Cleaner Air Oregon—Modeling Protocol and Risk Assessment Report

FormFactor, Inc.

Final

Prepared for:

Oregon Department of Environmental Quality

FormFactor, Inc.

June 23, 2023

Project No. M2417.01.002

Prepared by:

Maul Foster & Alongi, Inc.

6 Centerpointe Drive, Suite 360, Lake Oswego, OR 97035

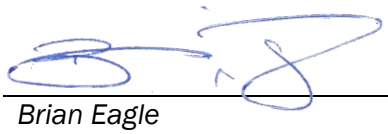
MAUL FOSTER ALONGI

Cleaner Air Oregon— Modeling Protocol and Risk Assessment Report

FormFactor, Inc.

The material and data in this report were prepared under the supervision and direction of the undersigned.

Maul Foster & Alongi, Inc.



Brian Eagle
Senior Environmental Scientist

Contents

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Tables

Abbreviations and Acronyms

ACDP	Air Contaminant Discharge Permit
the facility	flexible membrane circuit production and assembly facility located at 9100 SW Gemini Drive in Beaverton, Oregon
FormFactor	FormFactor, Inc.
MFA	Maul Foster & Alongi, Inc.
OAR	Oregon Administrative Rule
RA	Risk Assessment
RAL	Risk Action Level
RBC	risk-based concentration
RIE	reactive ion etching
TAC	toxic air contaminant
TEU	toxic emissions unit
VOC	volatile organic compound

1 Introduction

FormFactor, Inc. (FormFactor) owns and operates a flexible membrane circuit production and assembly facility located at 9100 SW Gemini Drive in Beaverton, OR, 97008 (the facility). The facility does not currently operate under an Air Contaminant Discharge Permit (ACDP).

FormFactor retained Maul Foster & Alongi, Inc. (MFA), to prepare and submit a Simple ACDP application for the facility. Per OAR 340-245-0050(2)(a)(A), all proposed new sources required to obtain a Simple ACDP must also perform a risk assessment to satisfy the requirements set forth under the CAO permitting program. FormFactor directed MFA to evaluate it as if it is a new source subject to -0050(2)(a)(A). This combined Modeling Protocol and Risk Assessment Report is being submitted with the Simple ACDP application to comply with the CAO permitting program under OAR 340-245.

The remainder of this report details the Level 1 Risk Assessment (RA) methodology and results, consistent with the requirements set forth under Oregon Administrative Rule (OAR) 340-245-0050(8).

2 Facility Description

2.1 Facility Location

The facility is located in Beaverton, Oregon, in the Nimbus Corporate Center. The area immediately surrounding the facility is relatively flat. The facility is direction surrounded by commercial land use, with residential further to the west. An aerial image of the facility location is shown in Figure 2-1. The topography of the area immediately surrounding the facility is shown in Figure 2-2. There is no elevated terrain nearby that would invalidate the assumptions used to develop the Level 1 RA per OAR 340-245-0050(8)(c).

2.2 Process Description

FormFactor manufactures flexible membrane circuits and assembles semiconductor testing and measurement systems and components.

Flexible membrane circuits are manufactured from substrate material which is processed through multiple fabrication steps. The area of the facility that manufactures flexible membrane circuits is referred to as the “Fab”. Activities within the Fab include deposition (layering, plating), coating, photolithography, and etching. The sequence and frequency of these activities will vary based on the type and design of each flexible membrane circuit being produced. Various solvents are also used within the Fab for cleaning.

Deposition processes used by the facility include sputtering (liberation of atoms from a target by a plasma followed by deposition onto the substrate), and electroplating (dipping of substrate into plating baths). Resins may be applied to the substrate as part of the deposition processes and may also be used as a mask agent prior to etching. Potential emissions related to deposition are primarily due to the use of volatile organic compound (VOC) containing resins and solvents, and acid gas emissions due to evaporation from plating baths. Deposition by electroplating may present a potential source of particulate emissions.

Photolithography is the process of applying a pattern to the surface of the substrate by selectively subjecting the substrate to a radiation source (such as light). Photolithography requires the use of photoresist products, photoresist stripping products, and solvents, each of which have volatile compounds that are assumed to be emitted.

The facility employs both wet and dry etching strategies in the Fab to assist with the selective removal of material from the substrate. Etching is typically done to remove materials from those areas that were modified as part of the photolithography step, and masking agents can be applied to protect specified areas from etching. Wet etching is performed in baths that typically contain acids and other compounds. Emissions from wet etching include the loss of volatile components of the bath contents, and acid gas emissions due to evaporation from the baths. Dry etching is performed using the reactive ion etching (RIE) process. For RIE, an etchant gas (tetrafluoromethane) is passed through a chemically reactive plasma. The fluoride ions released then react with the material deposited on the substrate, resulting in the removal of the deposited material in a controlled manner. Emissions from RIE include unreacted etchant gas, inorganic and organic fluoride compounds, and potentially hydrogen fluoride.

The facility also assembles components, such as probes, and performs testing on the components. Areas where this occurs are referred to as “Assembly.” Emissions from assembly and testing include volatile compounds from solvent usage, cleaning, and adhesive usage, and trace emissions due to soldering activities. Limited soldering is also performed in a PCB board assembly area.

Liquid waste generated by the Fab is directed to the facility’s wastewater treatment system, which filters and neutralizes the wastewater before discharge to the sewer. A portion of waste solvents from the Fab and Assembly are collected for transfer off-site.

A process flow diagram of the facility is provided in Figure 2-3. A plot plan of the facility is provided in Figure 2-4.

3 Emission Units and Emission Estimates

A detailed description of each emissions unit is provided in the following subsections. Figure 2-4 shows the approximate location of stacks where toxic air contaminants (TACs) are emitted. Daily and annual TAC emission estimates for process equipment considered to be toxic emissions units (TEUs) as defined in OAR 340-245-0060(1) were prepared by MFA and will be submitted with this report.

The following subsections detail the identified significant TEUs at the facility, as defined under OAR 340-245-0020(52) and describe how these sources are represented in the Level 1 RA. Level 1 RA inputs for the Significant TEU are presented in Table 3-1.

3.1 Fab

The process of manufacturing flexible membrane circuits involves the steps outlined in the process description in Section 2. Emission generating activities within the Fab are described in the following subsections. The facility is requesting that the Fab be considered the TEU, as the sequence and frequency of production activities will vary based on the type and design of each flexible membrane circuit being produced. The proposed TEU designation is consistent with the emissions unit designation proposed in the Simple ACDP application submitted by the facility. This proposed designation will allow the facility to remain responsive to customer demands and competitive within a dynamic industry.

The daily and annual TAC emission rates for the Fab are presented in Table 3-2. To allow the facility flexibility in operations within the Fab, conservative assumptions were made to apportion Fab emissions to the stacks with the highest dispersion factor for each exposure type. For the Residential (cancer and chronic noncancer) assessment, 100 percent of annual emissions have been assigned to stack ID EF-16. For the Nonresidential Worker (cancer and chronic noncancer) and Acute assessments, 100 percent of Fab emissions are apportioned exclusively to stack ID EF-10. For the Nonresidential Child (cancer and chronic noncancer) assessment, Fab emissions are apportioned exclusively to stack ID EF-22.

3.1.1 Deposition

Deposition primarily consists of plating and sputtering at the facility. Plating baths are sources of volatile and acid gas TAC emissions. Emissions from plating baths were conservatively estimated using pool evaporative calculations based on the highest temperature and highest acid concentration of each type of plating bath. Although the facility uses covers on most of the baths when not in use and adds wetting agents to the baths to minimize emissions, emission calculations for surface evaporation assume the baths are uncontrolled for conservatism. Particulate emissions are expected to be negligible given the small size of each bath, limited disturbance to the surface of each bath, and the use of wetting agents to minimize emissions. However, emissions of nickel and copper from plating were estimated consistent with publicly available emission factors. Volatile emissions from the plating baths were accounted for using a mass balance approach, assuming 100 percent of the volatile constituents used are emitted. Emissions from each plating bath are captured by backdraft hoods which vent emissions through stacks on the roof.

Sputtering is performed within vacuum chambers, where argon is used as a carrying gas. Metal liberated as part of the sputtering process is primarily deposited onto the substrate or surfaces within the sputtering equipment. Emissions from sputtering are expected to be negligible.

3.1.2 Coating

Emissions of volatile compounds present in resin coatings used in the Fab were accounted for using a mass balance approach, assuming 100 percent of the volatile constituents used are emitted. Coating is performed in various locations within the Fab.

3.1.3 Photolithography

Volatile TAC emissions from photolithography were estimated using a mass balance approach. The emissions inventory presented in Appendix A of the ADCP application estimates emissions assuming 100 percent of the volatile constituents present in materials used in the photoresist, edge bead remover, photoresist stripping chemicals, and drying in electrically heated ovens are emitted to air. The emission estimates assume that 100 percent of the volatile constituents of products used on-site are emitted, without consideration for volatile liquid waste discharged to the wastewater treatment system, or waste transferred offsite. This conservative assessment of volatile emissions based on usage rates represents potential volatile emissions at all steps within the Fab (including drying in electrically heated ovens), and overpredicts potential TAC emissions.

3.1.4 Etching

Emissions from wet etch baths are calculated in a manner similar to plating. Emissions from each wet etching bath are captured by backdraft hoods which vent emissions through stacks on the roof. Emissions from dry etching are calculated based on expected maximum carbon tetrafluoride usage rates. Emissions from dry etching include unreacted carbon tetrafluoride (a greenhouse gas), hydrogen fluoride, and total organic fluorides.

3.1.5 Cleaning

Emissions from cleaning agents, such as isopropyl alcohol, acetone, and methanol, are accounted for using a mass balance approach, assuming 100 percent of the volatile constituents used are emitted.

The emissions estimates assume that 100 percent of the volatile constituents of products used on-site are emitted, without consideration for volatile liquid waste discharged to the wastewater treatment system, or waste transferred offsite. This conservative assessment of volatile emissions based on usage rates represents potential volatile emissions at all steps within the Fab.

3.2 Assembly

Emissions from assembly are generated from adhesive usage, solvent usage, and soldering. Emissions were estimated assuming 100 percent volatilization of the volatile components of products used in the assembly area. Soldering that occurs as part of assembly may generate trace amounts of VOC and particulate emissions due to the heating of flux material. In a Soldering Operations document dated March 19, 1998, by the San Diego County Air Pollution Control District, “metal fume emissions from soldering are assumed to be negligible”, and visible “smoke” that may be observed from soldering is a “result of overheating the flux material” (SDCAPCP 1998).

3.3 Wastewater Treatment

The facility has on-site wastewater treatment equipment that neutralizes wastewater prior to discharge. Treatment is performed in holding tanks that have vent pipes. Because the purpose of the system is to neutralize wastewater, emissions are expected to be negligible. Potential emissions from any volatile compounds are accounted for in the mass balance calculations discussed

previously. Some waste solvents from Fab and Assembly are captured separately from the wastewater treatment stream for transport off-site.

3.4 Exempt TEUs

The facility uses natural gas for space heating and general HVAC at a few locations, and the units are only used on an as-needed basis for comfort heating. These heating units each have maximum heat input ratings below 0.4 million British thermal units per hour (MMBtu/hr), with the total heat input being below 0.75 MMBtu/hr. Natural gas combustion at the facility is considered categorically insignificant because the aggregate expected actual emissions do not exceed the de minimis level for any regulated pollutant and the sources do not exceed a heat rating of 2.0 MMBtu/hr, as defined in OAR 340-245-0060(3)(b)(B):

> *"Distillate oil, kerosene, gasoline, natural gas or propane burning equipment, provided the aggregate expected actual emissions of the equipment identified does not exceed the de minimis level for any regulated pollutant, based on the expected maximum annual operation of the equipment."*

The natural gas units meet the definition listed above and are therefore considered exempt TEUs. TAC emissions from these sources are not included in the Level 1 RA.

4 Risk Assessment

MFA estimated cancer and noncancer risk from the facility by conducting a Level 1 RA using the methodology outlined in OAR 340-245-0050(8) and the Level 1 RA directions from OAR 340-245-0200(2). The following subsections detail the inputs and assumptions used in support of the Level 1 RAs and the results of the RAs.

4.1 Exposure Locations

MFA conducted a Geographic Information System analysis of the land use zoning designations around the facility to determine the nearest exposure location for each of the four exposure classification types provided in OAR 340-245-8010 Table 2 (discussed below). Land-use information was obtained from Portland Metro. School locations were obtained from the Oregon Health Authority, and the Oregon Department of Education. Tax lot data were obtained from Washington County. Data from these sources were reviewed to determine the exposure locations nearest to the facility. Figure 4-1 presents a map depicting the unaltered land-use zoning in the 1-kilometer radius around the facility.

As noted above, MFA consolidated the land-use zoning regimes into the four classifications of exposure locations. The exposure location classifications are Residential, Nonresidential Worker, Nonresidential Child, and Acute Only. Locations considered to be right-of-ways are identified as Risk Not Assessed. To assess the accuracy of the land use zoning designations, an aerial imagery review was conducted of the area around the facility to verify that the land use zoning designations

corresponded to the correct exposure type. Figure 4-2 presents the land use zoning classifications, including modifications, that were used for the Level 1 RAs.

4.2 Dispersion Factors

MFA used the dispersion factors listed in OAR 340-245-8010, Table 3 for the Level 1 RAs. For each stack emission source, dispersion factors shown in Tables 3A and 3B were used to estimate cancer risk/chronic hazard index and acute hazard index, respectively. TEU stack height and distance to the nearest exposure locations, presented in Table 3-1, were used to determine applicable dispersion factors in Tables 3A and 3B. MFA assessed both Nonresidential Worker and Acute exposure using the distance from the TEU to the worker exposure location. This method results in Nonresidential Worker and Acute exposure distances less than the 50-meter minimum distance listed in OAR 340-245-8010, Table 3. MFA assessed Nonresidential Worker and Acute exposure using the 50-meter minimum distance listed in OAR 340-245-8010, Table 3. The dispersion factors for the significant TEU are presented in Table 4-1.

The distances from each TEU to the nearest exposure locations used in the Level 1 RAs were measured in ArcGIS. Because emissions from the Fab are distributed amongst multiple stacks, conservative assumptions have been made to apportion Fab emissions to the stack with the highest dispersion factor for each exposure type. For determination of Residential (cancer and chronic noncancer), 100 percent of annual emissions have been assigned to stack ID EF-16. For the Nonresidential Worker (cancer and chronic noncancer) and Acute assessments, 100 percent of Fab emissions are apportioned exclusively to stack ID EF-10. For the Nonresidential Child (cancer and chronic noncancer) assessment, Fab emissions are apportioned exclusively to stack ID EF-22. The distances from the TEU to the nearest exposure locations are shown in Figure 4-3. Actual emissions will be distributed amongst more stacks on the roof with overall better dispersion than demonstrated by the Level 1 RA.

4.3 Risk Calculations

The following risk calculations were performed separately for the significant TEUs and the gas combustion TEUs.

For each exposure location, the emission rate from each emission point was multiplied by the appropriate dispersion factor from OAR 340-245-8010, Table 3 to obtain a concentration in units of micrograms per cubic meter. The calculated concentration was then divided by the appropriate risk-based concentration (RBC) from OAR 340-245-8010, Table 2 to obtain risk estimates. These calculations are based on the equations below:

Equation 4-1.

$$\text{Excess cancer risk (chances in a million)} = \frac{(\text{TAC annual emission rate [lb/yr]}) \times \left(\text{TEU dispersion factor } \left[\frac{\text{ug/m}^3}{\text{lb/yr}}\right]\right)}{(\text{applicable RBC at exposure location [ug/m}^3\text{]})}$$

Equation 4-2.

$$\text{Chronic noncancer hazard index} = \frac{(\text{TAC annual emission rate [lb/yr]}) \times \left(\text{TEU dispersion factor } \left[\frac{\text{ug/m}^3}{\text{lb/yr}}\right]\right)}{(\text{applicable RBC at exposure location [ug/m}^3\text{]})}$$

Equation 4-3.

$$\text{Acute noncancer hazard index} = \frac{(\text{TAC daily emission rate [lb/day]}) \times \left(\text{TEU dispersion factor } \left[\frac{\text{ug/m}^3}{\text{lb/day}}\right]\right)}{(\text{applicable RBC at exposure location [ug/m}^3\text{]})}$$

Where:

lb/yr = pounds per year.
lb/day = pounds per day.
ug/m^3 = micrograms per cubic meter.

The resulting risk for each emitted TAC from a given TEU was summed to obtain the total risk estimate for that TEU at each exposure location. The total risk for each TEU was then summed to obtain the total facility risk estimate for each exposure location.

For the significant TEU, the cumulative risk estimate was compared against the Risk Action Levels (RALs) in OAR 340-245-8010, Table 1. The process was completed for each TEU and each exposure classification.

5 Risk Assessment Result Summary

MFA determined the total predicted excess cancer risk and chronic and acute noncancer risk (expressed numerically as the chronic and acute noncancer hazard index) at each modeled exposure location separately for significant TEUs and gas combustion TEUs following the applicable requirements set forth in OAR 340-245-0050(8) for a Level 1 RA. Results of the Level 1 RA are provided in the following subsections.

Table 5-1. Level 1 Risk Assessment Result Summary and RAL Evaluations

Exposure Assessment	New Source RAL			RA Result	RAL Analysis
	Aggregate TEU Level	Source Permit Level	Community Engagement Level		
Excess Cancer Risk (increased chances in a million)					
Residential	0.5	0.5	5	<0.1	Below Source Permit Level
Nonresidential Child				<0.1	Below Source Permit Level
Nonresidential Worker				<0.1	Below Source Permit Level
Chronic Noncancer Hazard Index					
Residential	0.1	0.5	1	<0.1	Below Source Permit Level
Nonresidential Child				<0.1	Below Source Permit Level
Nonresidential Worker				<0.1	Below Source Permit Level
Acute Noncancer Hazard Index					
Acute	0.1	0.5	1	0.1	Below Source Permit Level

Notes
RA = risk assessment.
RAL = Risk Action Level.
TEU = toxic emission unit.

5.1 Excess Cancer Risk

The maximum predicted excess cancer risk for the significant TEU is less than a 0.1 additional chance of developing cancer in a population of 1,000,000 people (chances in a million) as shown in Table 5-1.

5.2 Chronic Noncancer Hazard Index

The maximum predicted chronic noncancer hazard index for significant TEUs is less than 0.1 as shown in Table 5-1.

5.3 Acute Noncancer Hazard Index

The maximum predicted acute noncancer hazard index for significant TEUs is 0.1 as shown in Table 5-1.

5.4 Risk Action Level Analysis

The Level 1 RA cancer and noncancer results are presented in Table 5-2 and Table 5-3, respectively, for the significant TEU. Table 5-1, shown above, compares the noncancer hazard index estimates for each exposure assessment to the source RALs established in OAR 340-245-8010 Table 1. As shown in Table 5-1, all assessments are below the source permit RAL, so a CAO permit is not required for the facility.

6 Closing

MFA looks forward to working with the DEQ on this project. If there are any questions or comments regarding this report, please contact Brian Eagle at (971) 713-3571.

Limitations

The services undertaken in completing this report were performed consistent with generally accepted professional consulting principles and practices. No other warranty, express or implied, is made. These services were performed consistent with our agreement with our client. This report is solely for the use and information of our client unless otherwise noted. Any reliance on this report by a third party is at such party's sole risk.

Opinions and recommendations contained in this report apply to conditions existing when services were performed and are intended only for the client, purposes, locations, time frames, and project parameters indicated. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, or the use of segregated portions of this report.

Figures

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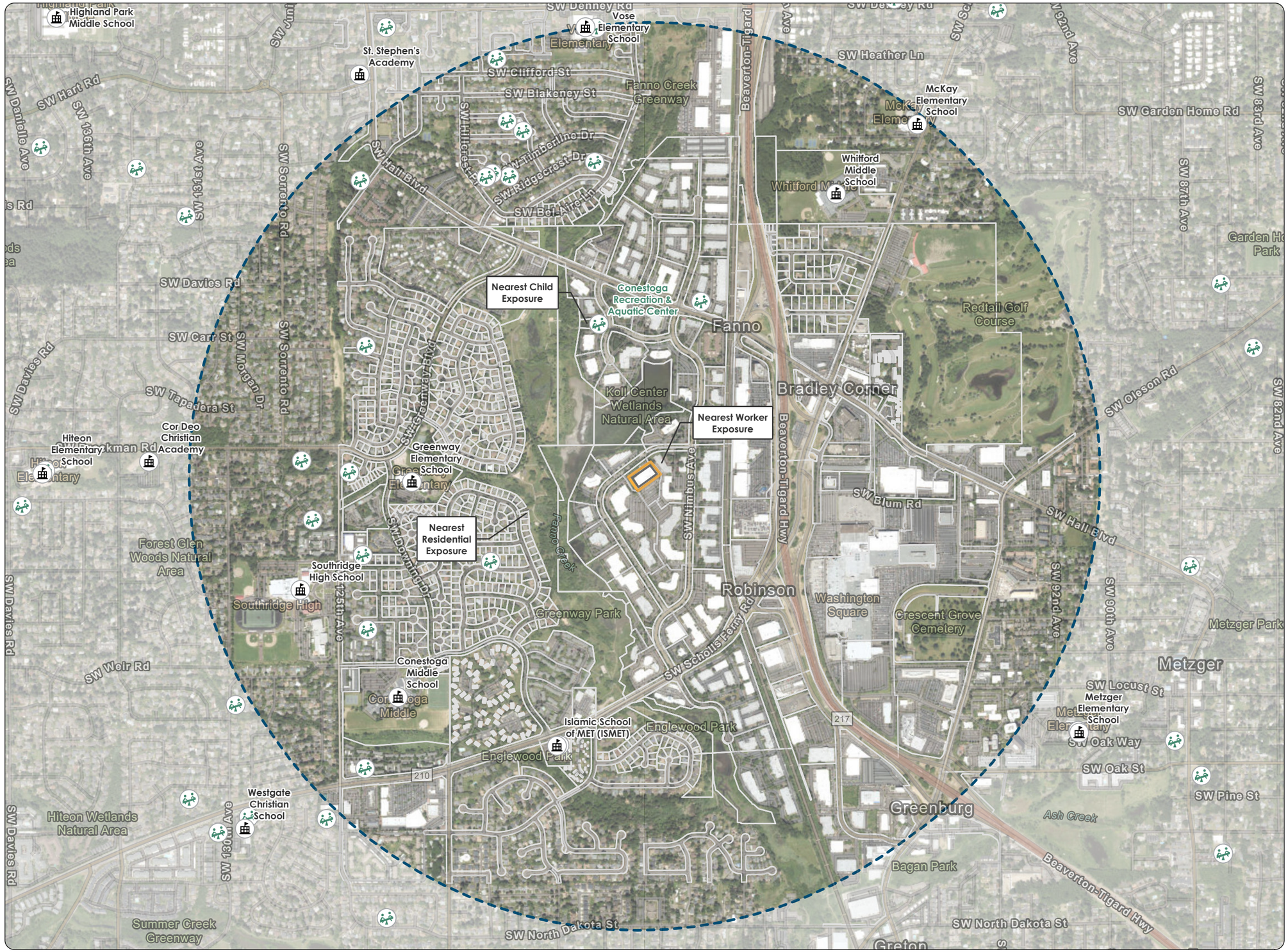
FOSTER
ALONGI

Figure 2-1
Aerial Image of Facility

FormFactor, Inc.
9100 SW Gemini Drive
Beaverton, OR



Legend

- Schools
- Early Learning Providers
- 1 Mile Facility Buffer
- Tax Lot
- Facility Boundary

Key Map

Note
No hospitals located in this map view.

0 1,000
Feet

Data Sources
Aerial photograph from City of Portland (2022); tax lots from Oregon Metro (2023); schools from Oregon Health Authority (2015-16 school year); early learning providers from Oregon Department of Education (2020).

MAUL FOSTER ALONGI
p. 971 544 2139 | www.maulfoster.com

Path: X:\O_MFA Projects\M2417\01\002\Proj\M2417_01_002_Air Level 1 Analysis.aprx\Fig 1 Facility Location
Print Date: 6/12/2023
Reviewed By: jdley
Produced By: jroberts
Project: M2417.01.002

Figure 2-2
Local Topography

FormFactor, Inc.
9100 SW Gemini Drive
Beaverton, OR

Legend

- Facility Boundary
- UTM 200 Meter Grid Mark

Key Map

0 800
Feet

Data Source
Topographic base from U.S. Geological Survey.

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UTM Y (meters): 5034400, 5034200, 5034000, 5033800, 5033600, 5033400, 5033200, 5033000, 5032800, 5032600, 5032400, 5032200

UTM X (meters): 514800, 515000, 515200, 515400, 515600, 515800, 516000, 516200, 516400, 516600, 516800, 517000, 517200, 517400, 517600, 517800

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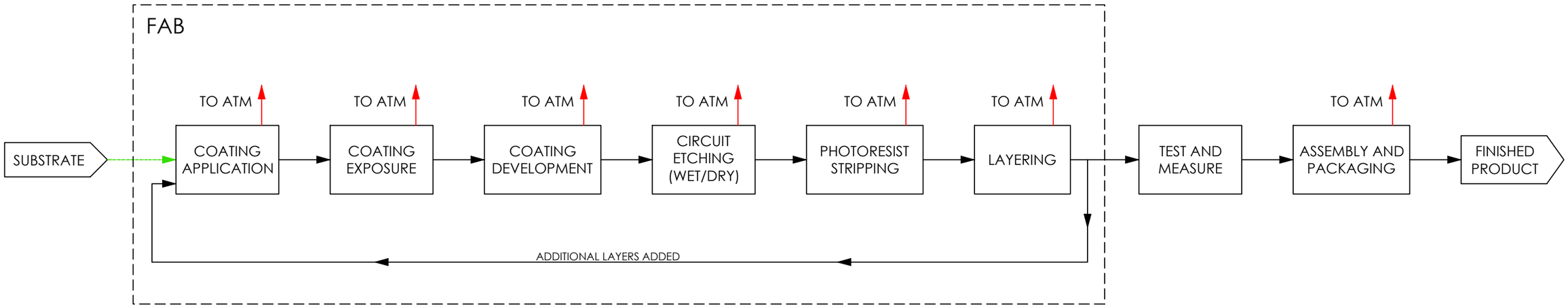
Print Date: 6/12/2023
Reviewed By: tfiley
Produced By: jroberts
Project: M2417.01.002



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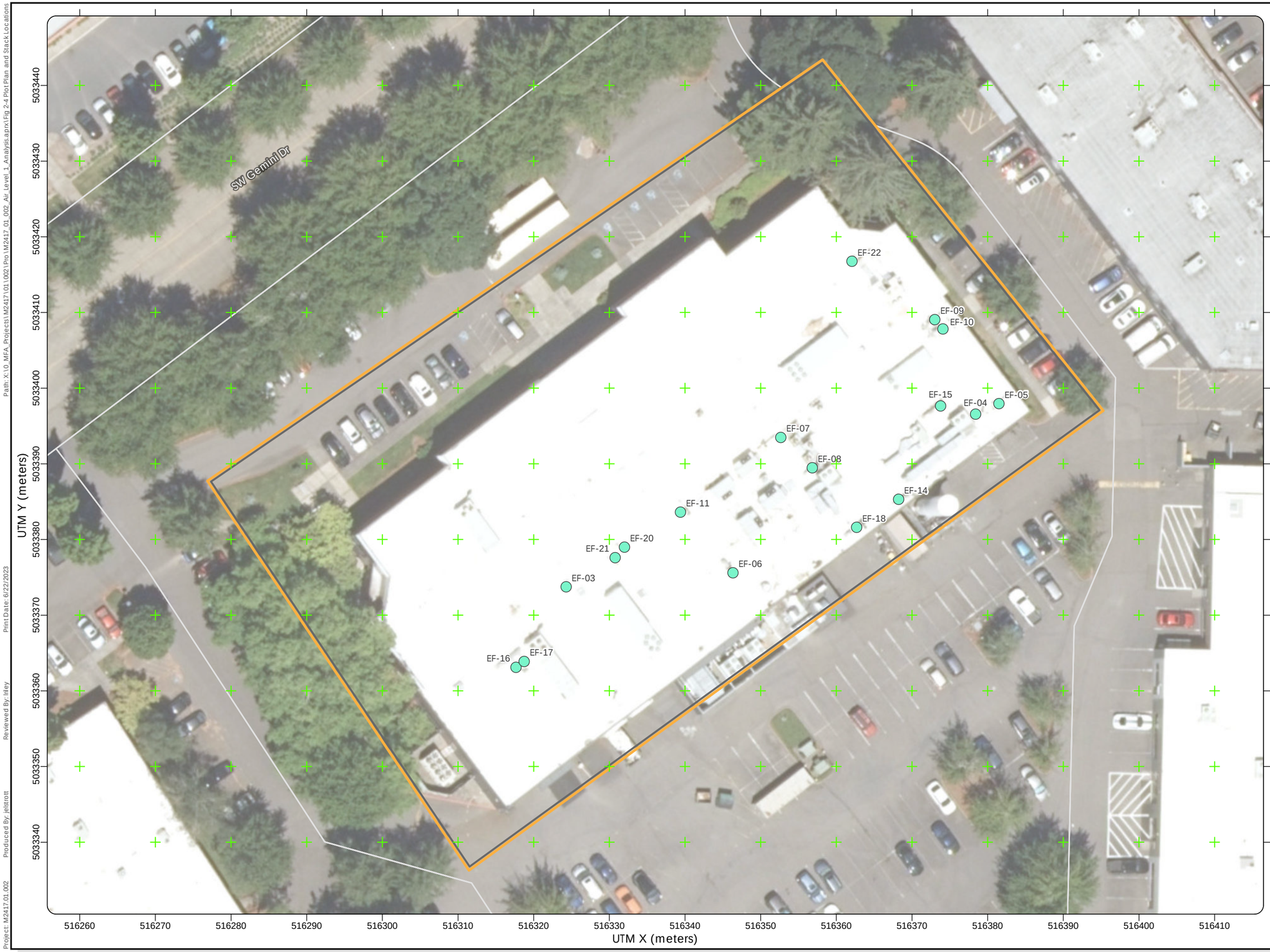
LEGEND:

- SUBSTRATE
- PRODUCT
- EMISSIONS TO ATMOSPHERE (VENT OR STACK)

Figure 2-3
Process Flow Diagram
FormFactor, Inc.
Beaverton, Oregon

Figure 2-4
Plot Plan and Stack Locations

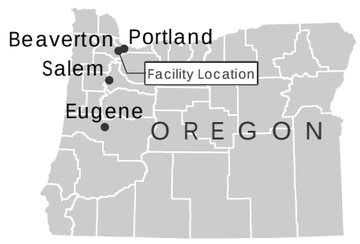
FormFactor, Inc.
9100 SW Gemini Drive
Beaverton, OR



Legend

- Stack Locations
- Facility Boundary
- Tax Lot

Key Map



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Feet

Data Source
Aerial photograph from City of Portland (2022.).

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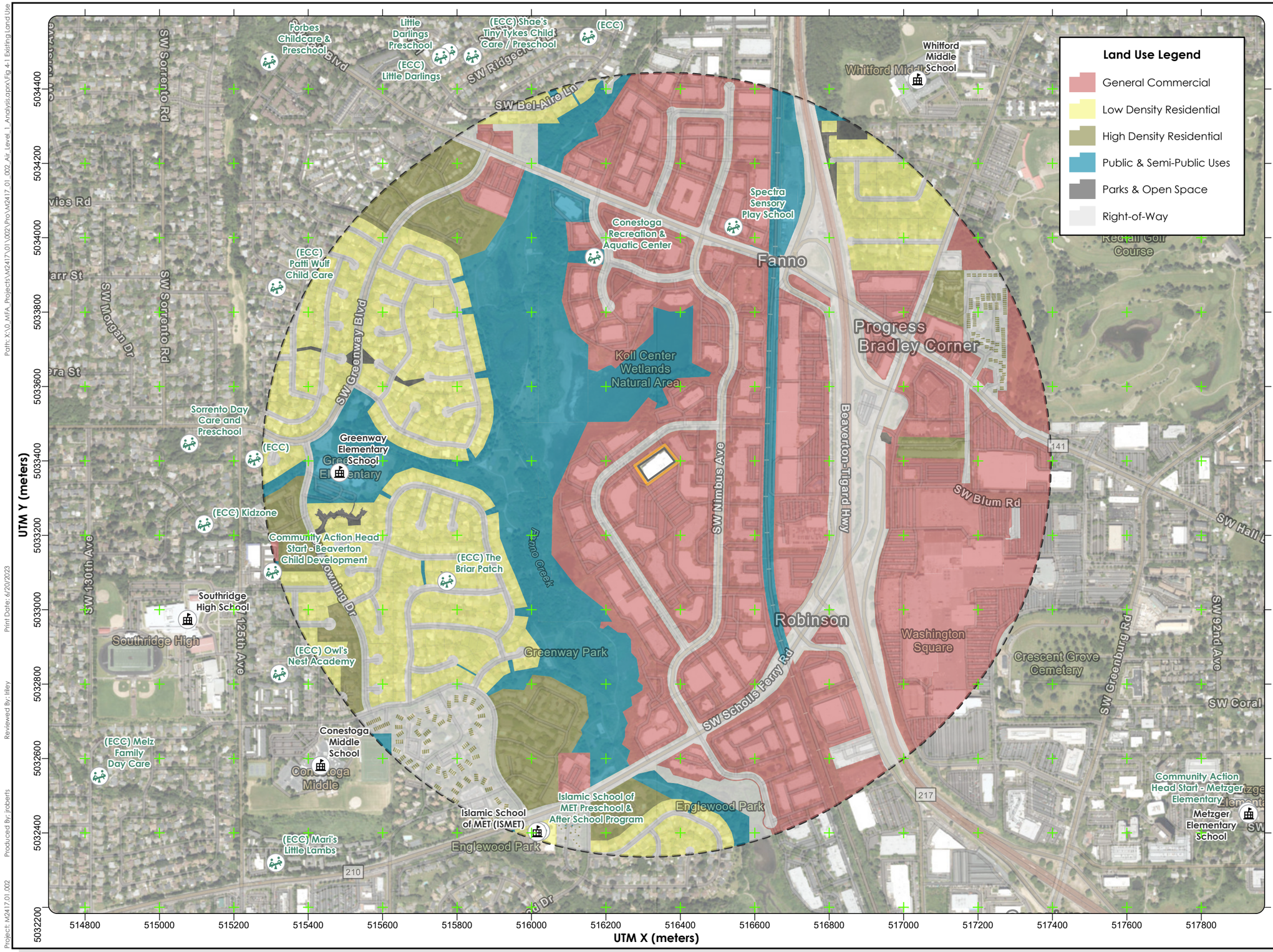
Path: X:\0_MFA_Projects\M2417\01\002\Pro\M2417_01_002_Air_Level_1_Analysis.aprx\Fig 2-4 Plot Plan and Stack Locations
Print Date: 6/22/2023
Reviewed By: Idley
Produced By: jelstrott
Project: M2417.01.002

Figure 4-1
Existing Land Use

FormFactor, Inc.
9100 SW Gemini Drive
Beaverton, OR



Key Map

Note
No hospitals located in this map view.

0 800
Feet

Data Sources
Aerial photograph from City of Portland (2022); land use from Oregon Metro (2023); schools from Oregon Health Authority (2015-16 school year); early learning providers from Oregon Department of Education (2020).

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Path: X:\O_MFA_Projects\M2417\01\002\Proj\M2417_01_002_Air_Level_1_Analysis.aprx\Fig 4-1 Existing Land Use
Print Date: 6/20/2023
Reviewed By: lriley
Produced By: jroberts
Project: M2417.01.002

Figure 4-2
Land Use Classifications

FormFactor, Inc.
9100 SW Gemini Drive
Beaverton, OR

RBC Basis Legend

- Child
- Residential
- Worker
- Acute Only
- Risk Not Assessed
- Revision of Land Use Based RBC

Legend

- Facility Boundary
- Tax Lot
- 1 Kilometer Facility Buffer
- UTM 200 Meter Grid Mark

Key Map

Notes

Current land use data obtained from Oregon Metro and is based on tax lots.
Current land use classifications revised to reflect RBC categories in Oregon Administrative Rule 340-245-8010 Table 2.
Rights of way will not be assessed for cancer or non-cancer risk.
RBC = risk-based concentration.

0 800
Feet

Data Sources

Aerial photograph from City of Portland (2022); tax lots from Oregon Metro (2023).

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UTM Y (meters): 5034400, 5034200, 5034000, 5033800, 5033600, 5033400, 5033200, 5033000, 5032800, 5032600, 5032400, 5032200

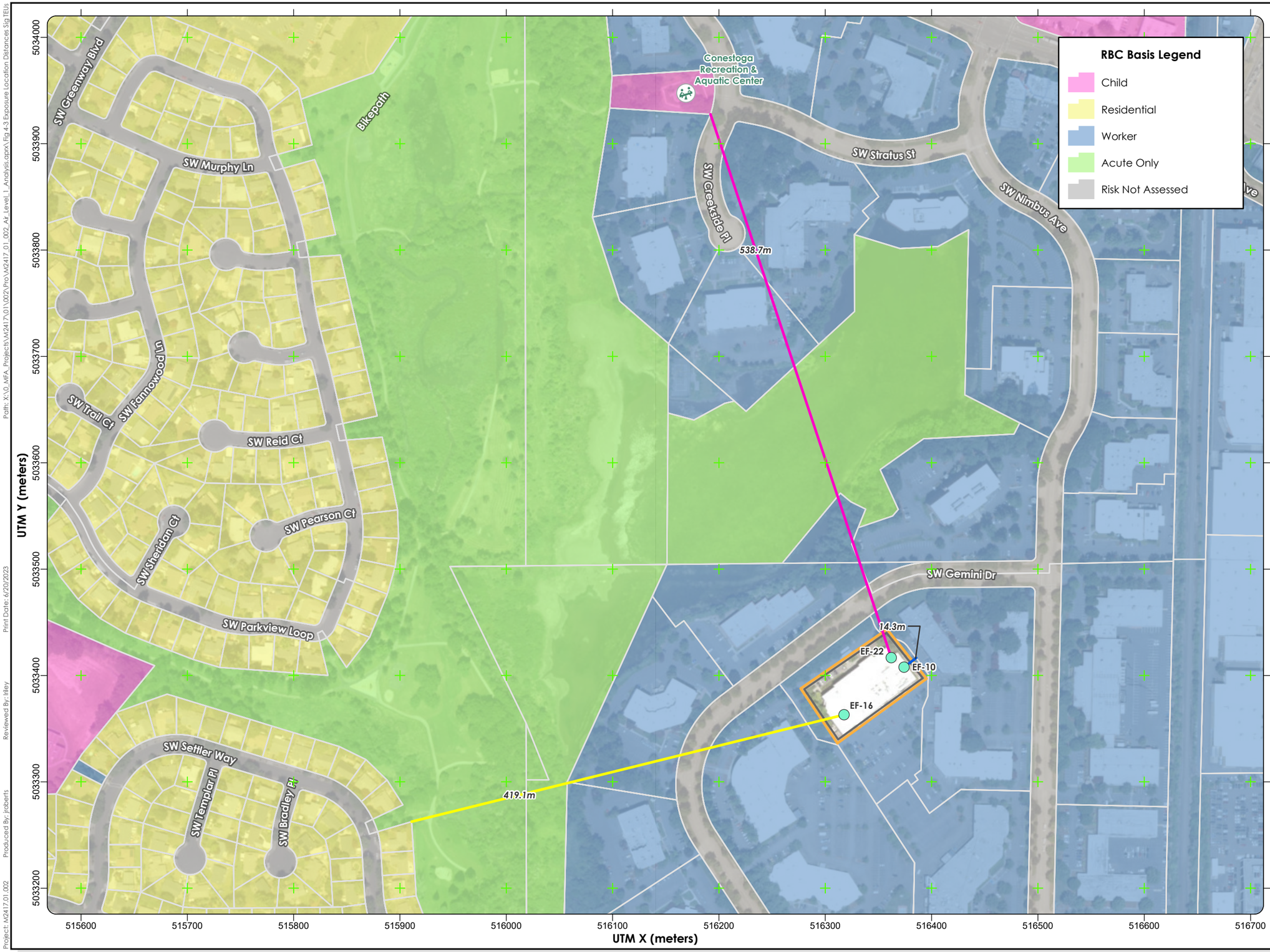
UTM X (meters): 514800, 515000, 515200, 515400, 515600, 515800, 516000, 516200, 516400, 516600, 516800, 517000, 517200, 517400, 517600, 517800

SW Cirrus Dr
SW Greenway Blvd
SW Hall Blvd
SW Creekside Pl
SW Stratus St
SW Beaverton Tigard Hwy
SW Crestwood Ct
SW Homestead Ln
SW Cascade Ave
SW Brightfield Cir
State Hwy 141
SW Ellander Ln
SW Murphy Ln
SW Rebecca Ln
SW Indian Hill Ln
SW Fannow Ln
SW Parkview Loop
Bikepath
SW Gemini Dr
SW Settler Way
SW Burnett Ln
SW Robbins Dr
SW Downing Dr
SW Wilkens Ln
SW Conestoga Dr
SW Trapper Ter
State Hwy 210
SW Eaglewood
SW Ironwood Loop
SW Scholls Ferry Rd
SW Nimbus Ave
State Hwy 217
SW Washington Square Rd

Path: X:\0_MFA_Projects\M2417\01\002\Pro\M2417_01_002_Air_Level_1_Analysis.aprx\Fig 4-2 Land Use Classifications
Print Date: 6/19/2023
Reviewed By: lifley
Produced By: jroberts
Project: M2417.01.002

Figure 4-3
Exposure Location Distances for the Significant TEU

FormFactor, Inc.
9100 SW Gemini Drive
Beaverton, OR



Legend

- Stack Locations

Shortest Line from Source to Receptor Property Boundary

- Child
- Residential
- Worker, Acute
- Early Learning Providers
- Facility Boundary
- Tax Lot
- UTM 100 Meter Grid Mark

Key Map

Notes

Current land use data obtained from Oregon Metro and is based on tax lots.
Current land use classifications revised to reflect RBC categories in Oregon Administrative Rule 340-245-8010 Table 2.
Rights of way will not be assessed for cancer or non-cancer risk.
RBC = risk-based concentration.

0 300
Feet

Data Sources

Aerial photograph from City of Portland (2022); tax lots from Oregon Metro (2023).

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Path: X:\0_MFA Projects\M2417\01\002\Pro\M2417_01_002_Ar_Level_1_Analysis.aprx\Fig 4-3 Exposure Location Distances Sig TEUs
Print Date: 6/20/2023
Reviewed By: Idley
Produced By: jroberts
Project: M2417 01 002

Tables

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Table 3-1
Level 1 Risk Assessment Inputs—Significant TEU
FormFactor, Inc.

Unit ID	Unit Name	Release Parameter		Exposure Location Distance (m)			
		Stack or Fugitive?	Stack Height [1] (m)	Chronic			Acute [3]
				Residential [2]	Nonresidential Child [2]	Nonresidential Worker [3]	
Significant TEU							
EF-10	FAB—Closest Stack to Nonresidential Worker and Acute Location	Stack	9.1	--	--	50.0	50.0
EF-16	FAB—Closest Stack to Residential Location	Stack	7.9	419	--	--	--
EF-22	FAB—Closest Stack to Nonresidential Child Location	Stack	7.9	--	539	--	--

Notes

m = meter

References

[1] Information provided by FormFactor, Inc.

[2] Exposure location distances were measured in ArcGIS from the source location to the property line of the closest exposure location type.

[3] The nearest Nonresidential Worker and Acute exposure distances are less than the 50-m minimum distance listed in OAR 340-245-8010, Table 3; therefore, 50 m was assumed.

Table 3-2
Level 1 Risk Assessment Emission Rates—Significant TEU
FormFactor, Inc.

Toxic Air Contaminant	CAS	RBC? (Yes/No)	Emissions Estimate [1]									
			Mass Balance		Acid Baths		Plating Particulate		Dry Etching		FAB Total	
			(lb/day)	(lb/yr)	(lb/day)	(lb/yr)	(lb/day)	(lb/yr)	(lb/day)	(lb/yr)	(lb/day)	(lb/yr)
Metals												
Copper and Compounds	7440-50-8	Yes	--	--	--	--	8.6E-04	0.32	--	--	**8.6E-04**	**0.32**
Nickel and Compounds	7440-02-0	Yes	--	--	--	--	7.7E-07	2.8E-04	--	--	**7.7E-07**	**2.8E-04**
Organic Compounds												
1-Methoxy-2-propanol	107-98-2	Yes	150	10,939	--	--	--	--	--	--	**150**	**10,939**
1-Methoxy-2-propanol acetate	108-65-6	Yes	81.6	5,840	--	--	--	--	--	--	**81.6**	**5,840**
Acetone	67-64-1	Yes	53.4	3,872	--	--	--	--	--	--	**53.4**	**3,872**
Bis (2-methoxyethyl) ether	111-96-6	Yes	46.7	3,417	--	--	--	--	--	--	**46.7**	**3,417**
Ethylene Glycol	107-21-1	Yes	9.29	9.29	--	--	--	--	--	--	**9.29**	**9.29**
Isopropanol	67-63-0	Yes	45.5	3,327	--	--	--	--	--	--	**45.5**	**3,327**
Methanol	67-56-1	Yes	7.90	379	--	--	--	--	--	--	**7.90**	**379**
Inorganic Compounds												
Hydrochloric Acid	7647-01-0	Yes	--	--	0.77	283	--	--	--	--	**0.77**	**283**
Hydrofluoric Acid	7664-39-3	Yes	--	--	--	--	--	--	0.12	8.45	**0.12**	**8.45**
Nitric Acid	7697-37-2	Yes	--	--	0.043	15.8	--	--	--	--	**0.043**	**15.8**
Phosphoric Acid	7664-38-2	Yes	--	--	0.17	62.2	--	--	--	--	**0.17**	**62.2**
Sulfuric acid	7664-93-9	Yes	--	--	7.9E-06	2.9E-03	--	--	--	--	**7.9E-06**	**2.9E-03**

Notes

RBC = risk-based concentration

References

[1] Facility emissions are from the toxic air contaminant emissions inventory.

Table 4-1
TEU Dispersion Factors—Significant TEU
FormFactor, Inc.

Stack ID	Stack Description	Dispersion Factor			
		Annual Exposure [1] ($ug/m^3/lb/yr$)			Daily Exposure [2] ($ug/m^3/lb/day$)
		Residential	Nonresidential Child	Nonresidential Worker	Acute
Significant TEU					
EF-10	FAB—Closest Stack to Nonresidential Worker and Acute Location	--	--	1.7E-03	4.57
EF-16	FAB—Closest Stack to Residential Location	9.18E-05	--	--	--
EF-22	FAB—Closest Stack to Nonresidential Child Location	--	6.00E-05	--	--

Notes

lb = pound

m^3 = cubic meter

ug = microgram

yr = year

References

[1] OAR 340-245-8010 Table 3A, "Stack Emission Dispersion Factors for Annual Exposure (ug/m^3/pounds/year)." Values were interpolated between the closest dispersion factors for both the TEU release height and the exposure location distance.

[2] OAR 340-245-8010 Table 3B, "Stack Emission Dispersion Factors for 24 hour Exposure (ug/m^3/pounds/day)." Values were interpolated between the closest dispersion factors for both the TEU release height and the exposure location distance.

Table 5-2
Level 1 Cancer Risk Assessment Summary—Significant TEU
FormFactor, Inc.

Toxic Air Contaminant	CAS	TAC Annual Emission Rates [1] (lb/yr)	Residential Exposure		Nonresidential Child Exposure		Nonresidential Worker Exposure	
			RBC (ug/m^3)	Excess Cancer Risk [a]	RBC (ug/m^3)	Excess Cancer Risk [a]	RBC (ug/m^3)	Excess Cancer Risk [a]
Cumulative Facility-Wide Risk			**--**	**6.75E-06**	**--**	**1.68E-07**	**--**	**1.05E-05**
Risk Comparison Value [2]			**--**	**<0.1**	**--**	**<0.1**	**--**	**<0.1**
TEU FAB Stack ID [3]			**EF-16**		**EF-22**		**EF-10**	
TEU Dispersion Factor (ug/m^3/lb/yr) [4]			**9.2E-05**		**6.0E-05**		**1.73E-03**	
Copper and Compounds	7440-50-8	0.32	--	--	--	--	--	--
Nickel and Compounds	7440-02-0	2.8E-04	3.8E-03	6.7E-06	0.10	1.7E-07	0.046	1.0E-05
1-Methoxy-2-propanol	107-98-2	10,939	--	--	--	--	--	--
1-Methoxy-2-propanol acetate	108-65-6	5,840	--	--	--	--	--	--
Acetone	67-64-1	3,872	--	--	--	--	--	--
Bis (2-methoxyethyl) ether	111-96-6	3,417	--	--	--	--	--	--
Ethylene Glycol	107-21-1	9.29	--	--	--	--	--	--
Isopropanol	67-63-0	3,327	--	--	--	--	--	--
Methanol	67-56-1	379	--	--	--	--	--	--
Hydrochloric Acid	7647-01-0	283	--	--	--	--	--	--
Hydrofluoric Acid	7664-39-3	8.45	--	--	--	--	--	--
Nitric Acid	7697-37-2	15.8	--	--	--	--	--	--
Phosphoric Acid	7664-38-2	62.2	--	--	--	--	--	--
Sulfuric acid	7664-93-9	2.9E-03	--	--	--	--	--	--

Notes

ug/m^3 = microgram per cubic meter.

RBC = risk-based concentration

TAC = Toxic Air Contaminant.

TEU = toxic emission unit.

[a] Excess cancer risk = (TAC annual emission rate [lb/yr]) x (TEU dispersion factor [ug/m^3/lb/yr]) / (RBC [ug/m^3])

References

[1] See Table 3-2, Level 1 Risk Assessment Emission Rates—Significant TEU.

[2] Risk comparison value is the facility total risk rounded in accordance with OAR 340-245-0200(4)(a)(A).

[3] 100 percent of emissions from the FAB TEU are allocated to the closest stack for each exposure type.

[4] See Table 4-1, TEU Dispersion Factors—Significant TEU.

Table 5-3
Level 1 Noncancer Risk Assessment Summary—Significant TEU
FormFactor, Inc.

TAC	CAS	TAC Emission Rate [1]		Chronic Noncancer						Acute Noncancer	
				Residential		Nonresidential Child		Nonresidential Worker			
		Daily (lb/day)	Annual (lb/yr)	RBC (ug/m^3)	Hazard Index [a]	RBC (ug/m^3)	Hazard Index [a]	RBC (ug/m^3)	Hazard Index [a]	RBC (ug/m^3)	Hazard Index [b]
Cumulative Facility-Wide Risk				--	**3.9E-03**	--	**5.6E-04**	--	**0.016**	--	**0.13**
Risk Comparison Value [2]				--	**<0.1**	--	**<0.1**	--	**<0.1**	--	**0.1**
TEU FAB Stack ID [3]				**EF-16**		**EF-22**		**EF-10**		**EF-10**	
TEU Dispersion Factor (ug/m^3/lb/yr) [4]				**9.18E-05**		**6.00E-05**		**1.73E-03**		**--**	
TEU Dispersion Factor (ug/m^3/lb/day) [4]				**--**		**--**		**--**		**4.57**	
Copper and Compounds	7440-50-8	8.6E-04	0.32	--	--	--	--	--	--	100	3.95E-05
Nickel and Compounds	7440-02-0	7.7E-07	2.8E-04	0.014	1.83E-06	0.062	2.70E-07	0.062	7.77E-06	0.20	1.75E-05
1-Methoxy-2-propanol	107-98-2	150	10,939	7,000	1.43E-04	31,000	2.12E-05	31,000	6.09E-04	--	--
1-Methoxy-2-propanol acetate	108-65-6	81.6	5,840	--	--	--	--	--	--	--	--
Acetone	67-64-1	53.4	3,872	31,000	1.15E-05	140,000	1.66E-06	140,000	4.77E-05	62,000	3.94E-03
Bis (2-methoxyethyl) ether	111-96-6	46.7	3,417	--	--	--	--	--	--	--	--
Ethylene Glycol	107-21-1	9.29	9.29	400	2.13E-06	1,800	3.10E-07	1,800	8.90E-06	2,000	0.021
Isopropanol	67-63-0	45.5	3,327	200	1.53E-03	880	2.27E-04	880	6.52E-03	3,200	0.065
Methanol	67-56-1	7.90	379	4,000	8.71E-06	18,000	1.26E-06	18,000	3.64E-05	28,000	1.29E-03
Hydrochloric Acid	7647-01-0	0.77	283	20.0	1.30E-03	88.0	1.93E-04	88.0	5.54E-03	2,100	1.69E-03
Hydrofluoric Acid	7664-39-3	0.12	8.45	2.10	3.69E-04	19.0	2.67E-05	19.0	7.67E-04	16.0	0.033
Nitric Acid	7697-37-2	0.043	15.8	--	--	--	--	--	--	86.0	2.29E-03
Phosphoric Acid	7664-38-2	0.17	62.2	10.0	5.71E-04	44.0	8.48E-05	44.0	2.44E-03	--	--
Sulfuric acid	7664-93-9	7.9E-06	2.9E-03	1.00	2.64E-07	4.40	3.92E-08	4.40	1.13E-06	120	3.00E-07

Notes

ug/m^3 = microgram per cubic meter.

RBC = risk-based concentration

TAC = Toxic Air Contaminant.

TEU = toxic emission unit.

[a] Chronic noncancer hazard index = (TAC annual emission rate [lb/yr]) x (TEU dispersion factor [ug/m^3/lb/yr]) / (RBC [ug/m^3])

[b] Acute noncancer hazard index = (TAC daily emission rate [lb/day]) x (TEU dispersion factor [ug/m^3/lb/day]) / (RBC [ug/m^3])

References

[1] See Table 3-2, Level 1 Risk Assessment Emission Rates—Significant TEU.

[2] Risk comparison value is the facility total risk rounded in accordance with OAR 340-245-0200(4)(a)(A).

[3] 100 percent of emissions from the FAB TEU are allocated to the closest stack for each exposure type.

[4] See Table 4-1, TEU Dispersion Factors—Significant TEU.

State of Oregon
DEQ Department of Environmental Quality

Cleaner Air Oregon Pre-Application Fee Form

Form AQ500

DEQ Use Only			
Permit Number:		Type of Application:	
Application Number:			
Date Received:			
Region: NWR - AQ Permit Coordinator		Check No.:	Amount:

1. Company Information			**2. Facility Location Information**		
Legal Name: FormFactor Inc.			Name: FormFactor Inc.		
Mailing Address: 7005 Southfront Rd.			Street Address: 9100 SW Gemini Dr		
City: Livermore	State: CA	ZIP Code: 94551	City: Beaverton	County: Washington	ZIP Code: 97008

3. Site Contact Person	**4. Industrial Classification Code(s)**
Name: Mark Bruch	Primary SIC and NAICS: 3674 and 334413
Title: EHS Manager	Secondary SIC and NAICS: 3679 and 334515
Telephone number: 503-601-1700	**5. Other DEQ Permits** N/A
Fax number:	
Email address: mark.bruch@formfactor.com	

6. Permit Action:

		√	Title V or Standard ACDP	√	Simple ACDP	√	General or Basic ACDP
1	Existing Source Call-In Fee	☐	$10,000	☐	$1,000	☐	$500
2	New Source Consulting Fee	☐	$12,000	☑	$1,900	☐	$1,000

Amount Due: $ 1,900.00

Please attach check payable to Oregon Dept. of Environmental Quality, and mail to:

Oregon Dept. of Environmental Quality
Financial Services - Revenue Section
700 NE Multnomah St., Suite 600
Portland, Oregon 97232-4100

If you don't know which permit type applies to your facility, please contact DEQ, contact information can be found here: www.oregon.gov/deq/aq/aqPermits/Pages/Contacts.aspx

Form AQ523

CATEGORICALLY EXEMPT TOXICS EMISSIONS UNITS **ANSWER SHEET**

Facility name: FormFactor Inc. Permit Number:

Indicate which of the following categorically exempt activities occur at this facility by checking the appropriate columns below. Submit this form electronically with your Cleaner Air Oregon (CAO) Emissions Inventory AQ520 form to meet the reporting requirements in OAR 340-245-0040(4)(a)(A) for categorically exempt Toxics Emissions Units (TEUs). This form is the complete list of categorically exempt TEUs, which can be found in the division 245 rules under OAR 340-245-0060(3)(b).

Yes	No	Categorically Exempt TEU Activities
☐	☑	Evaporative and tail pipe emissions from on-site motor vehicle operation.
☑	☐	Distillate oil, kerosene, gasoline, natural gas or propane burning equipment, provided the aggregate expected actual emissions of the equipment identified does not exceed the de minimis level for any regulated pollutant, based on the expected maximum annual operation of the equipment. If a source's expected emissions from all such equipment exceed the de minimis levels, then the source may identify a subgroup of such equipment as categorically exempt with the remainder not designated as an exempt TEU. The following equipment may never be included as part of the exempt TEU: A. Any individual distillate oil, kerosene or gasoline burning equipment with a rating greater than 0.4 million Btu/hour; and B. Any individual natural gas or propane burning equipment with a rating greater than 2.0 million Btu/hour.
☐	☑	Distillate oil, kerosene, gasoline, natural gas or propane burning equipment brought on site for six months or less for maintenance, construction or similar purposes, such as but not limited to generators, pumps, hot water pressure washers and space heaters, provided that any such equipment that performs the same function as the permanent equipment, must be operated within the source's existing PSEL.
☑	☐	Office activities.
☑	☐	Food service activities.
☑	☐	Janitorial activities.
☑	☐	Personal care activities.
☐	☑	Grounds keeping activities, including, but not limited to building painting and road and parking lot maintenance.
☐	☑	On-site laundry activities.
☐	☑	On-site recreation facilities.
☑	☐	Instrument calibration.
☐	☑	Automotive storage garages.

☑	☐	Refrigeration systems with less than 50 pounds of charge of ozone depleting substances regulated under Title VI, including pressure tanks used in refrigeration systems but excluding any combustion equipment associated with such systems.
☑	☐	Temporary construction activities.
☑	☐	Warehouse activities.
☑	☐	Accidental fires and fire suppression.
☑	☐	Air vents from compressors.
☑	☐	Air purification systems.
☐	☑	Continuous emissions monitoring lines.
☑	☐	Demineralized water tanks.
☑	☐	Pre-treatment of municipal water, including use of deionized water purification systems.
☑	☐	Electrical charging stations.
☐	☑	Fire brigade training.
☐	☑	Instrument air dryers and distribution.
☐	☑	Fully enclosed process raw water filtration systems.
☑	☐	Electric motors.
☑	☐	Pressurized tanks containing gaseous compounds that do not contain toxic air contaminants.
☐	☑	Vacuum sheet stacker vents.
☑	☐	Emissions from wastewater discharges to publicly owned treatment works (POTW) provided the source is authorized to discharge to the POTW, not including on-site wastewater treatment and/or holding facilities.
☐	☑	Log ponds.
☐	☑	Stormwater settling basins.
☑	☐	Paved roads and paved parking lots within an urban growth boundary.
☑	☐	Hazardous air pollutant emissions in fugitive dust from paved and unpaved roads except for those sources that have processes or activities that contribute to the deposition and entrainment of hazardous air pollutants from surface soils.
☑	☐	Health, safety, and emergency response activities.
☐	☑	Non-diesel, compression ignition emergency generators* and pumps used only during loss of primary equipment or utility service due to circumstances beyond the

		reasonable control of the owner or operator, or to address a power emergency, provided that the aggregate horsepower rating of all stationary emergency generator and pump engines is not more than 3,000 horsepower. If the aggregate horsepower rating of all the stationary emergency generator and pump engines is more than 3,000 horsepower, then no emergency generators and pumps at the source may be considered categorically exempt. ***All spark ignition engines remain exempt.**
☐	☑	Non-contact steam vents and leaks and safety and relief valves for boiler steam distribution systems.
☐	☑	Non-contact steam condensate flash tanks.
☐	☑	Non-contact steam vents on condensate receivers, deaerators and similar equipment.
☐	☑	Boiler blowdown tanks.
☐	☑	Ash piles maintained in a wetted condition and associated handling systems and activities.