

Health Impact Assessment
for a Lumber
Manufacturing Facility
Frederickson, Washington

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1 Introduction

Sierra Pacific Industries (SPI) proposes to construct and operate a stud lumber manufacturing facility (hereafter, “the Facility”) at a site in Pierce County near Frederickson, Washington. The Facility will produce up to approximately 300 million board feet (MMbf) of dimensional lumber per year. The proposed site of the Facility, which is part of the recently developed Frederickson Industrial Park, is located at 3501 208th Street East in unincorporated Pierce County, southwest of Frederickson.

Because Pierce County is within the jurisdiction of the Puget Sound Clean Air Agency (PSCAA), the proposed Facility must comply with regulations adopted by that agency, as applicable. As a proposed new source of air pollutants, a Notice of Construction (NOC) permit application was submitted to PSCAA, along with all required fees, on February 3, 2014.

Toxic air pollutant (TAP) emission rates calculated using representative emission factors and maximum potential operating schedules were provided in the NOC permit application. Eight TAPs were determined to exceed the Small Quantity Emission Rates (SQERs) provided in WAC 173-460-150 for those particular substances. A dispersion modeling analysis, using the AERMOD modeling system, was employed to predict ambient concentrations attributable to these SQER-exceeding TAP emissions. The modeling analysis indicated that three of the modeled TAPs exceeded the Acceptable Source Impact Levels (ASILs) provided in WAC 173-460-150: acetaldehyde, acrolein, and formaldehyde.

The remainder of this document consists of a description of the source, including calculated TAP emission rates, an outline of the air dispersion modeling methodology, including inputs and assumptions, the results of the modeling, and risk calculation information for TAPs predicted to exceed both the SQERs and ASILs.

2 Project Description

2.1 Project Location

As stated in the previous section, the Facility is located at 3501 208th Street East in unincorporated Pierce County, near Frederickson, Washington. Aerial photos showing the location and layout of the Facility are provided in Figures 2-1 and 2-2.

The demographics of Pierce County, as well as the cities of Frederickson and Spanaway, which are near the Facility, are summarized in Table 2-1. All data were obtained from the U.S. Census Bureau, and represent data from the 2010 census.

Table 2-1. Demographics of Nearby Jurisdictions

Metric	Pierce County	Frederickson	Spanaway
Population, 2010	795,225	18,719	27,227
Percent of persons under 5 years, 2010	7.0%	8.9%	8.1%
Percent of persons under 18 years, 2010	24.9%	29.3%	28.2%
Percent of persons 65 years and over, 2010	11.0%	6.9%	9.2%

The Facility is located in the Frederickson Employment Center, the largest designated industrial area in Pierce County. The Employment Center is its own zoning designation, “a concentration of low to high intensity office parks, manufacturing, other industrial development, or a combination of activities.” Areas to the east and west of the Facility are also within the Frederickson Community Plan Area, and are zoned “Moderate Density Single Family.” The area to the north is part of the Frederickson Employment Center. The area to the south is in unincorporated Pierce County, outside the Frederickson Community Plan Area, and is zoned “Rural Reserve 5,” which “is intended to provide lands for potential future inclusion in an urban growth area when the need for additional land is identified and a Plan amendment is adopted.” Figure 2-3 presents the current zoning in the areas surrounding the Facility.

The nearest residence, which is also in the Frederickson Employment Center, is located approximately 50 meters (m) from the south property boundary of the proposed Facility. Other residential areas lie approximately 220 m to the east, and 150 m to the west.

2.2 Emission Units

The Facility will be a lumber manufacturing facility that will produce two-by-four and two-by-six dimensional lumber, often referred to as “stud lumber,” from relatively small diameter logs. The principle components of the Facility will include a log storage area consisting of log “decks;” buildings enclosing a sawmill and a planer mill; a natural gas-fired package boiler; and six steam-heated kilns to dry lumber. Figure 2-4 presents the layout of the structures associated with the proposed project. The package boiler and lumber dry kilns will be the only sources of TAPs.

2.3 Emission Rate Calculations

2.3.1 Package Boiler

The natural gas-fired package boiler will have a rated capacity of 100 million British thermal units per hour (MMBtu/hr) or less. Boiler operation and loading will be dictated entirely by kiln operations, which could result in continuous, year-round operation. Calculated potential hourly and annual TAP emission rates are summarized in Table 2-2. Annual emission are based on full-capacity operation throughout the year (i.e., 8,760 hours)

Table 2-2. Package Boiler Potential Toxic Air Pollutant Emissions

Pollutant	CAS #	Emission Factor ¹ (lb/MMscf)	(lb/hr)	(lb/day)	(lb/yr)
Arsenic	7440-38-2	0.0002	1.96E-05	4.71E-04	1.72E-01
Benzene	71-43-2	0.0021	2.06E-04	4.94E-03	1.80E+00
Benzo(a)anthracene	56-55-3	0.0000018	1.76E-07	4.24E-06	1.55E-03
Benzo(a)pyrene	50-32-8	0.0000012	1.18E-07	2.82E-06	1.03E-03
Benzo(b)fluoranthene	205-99-2	0.0000018	1.76E-07	4.24E-06	1.55E-03
Benzo(k)fluoranthene	207-08-9	0.0000018	1.76E-07	4.24E-06	1.55E-03
Beryllium	7440-41-7	0.000012	1.18E-06	2.82E-05	1.03E-02
Cadmium	7440-43-9	0.0011	1.08E-04	2.59E-03	9.45E-01
Carbon monoxide	630-08-0	0.036	3.60E+00	8.64E+01	3.15E+04
Chromium, (hexavalent)	18540-29-9	0.000056	5.49E-06	1.32E-04	4.81E-02
Chrysene	218-01-9	0.0000018	1.76E-07	4.24E-06	1.55E-03
Cobalt	7440-48-4	0.000084	8.24E-06	1.98E-04	7.21E-02
Copper	7440-50-8	0.00085	8.33E-05	2.00E-03	7.30E-01
Dibenzo(a,h)anthracene	53-70-3	0.0000012	1.18E-07	2.82E-06	1.03E-03
7,12-Dimethylbenz(a)anthracene	57-97-6	0.000016	1.57E-06	3.76E-05	1.37E-02
Formaldehyde	50-00-0	0.075	7.35E-03	1.76E-01	6.44E+01
Hexane	110-54-3	1.8	1.76E-01	4.24E+00	1.55E+03
Indeno(1,2,3-cd)pyrene	193-39-5	0.0000018	1.76E-07	4.24E-06	1.55E-03
Manganese	7439-96-5	0.00038	3.73E-05	8.94E-04	3.26E-01
Mercury	7439-97-6	0.00026	2.55E-05	6.12E-04	2.23E-01
3-Methylchloranthrene	56-49-5	0.0000018	1.76E-07	4.24E-06	1.55E-03
Naphthalene	91-20-3	0.00061	5.98E-05	1.44E-03	5.24E-01
Nitrogen dioxide	10102-44-0	0.011	1.10E+00	2.64E+01	9.64E+03
Selenium	7782-49-2	0.000024	2.35E-06	5.65E-05	2.06E-02
Sulfur dioxide	7446-09-5	0.00725 / 0.00367	7.25E-01	1.74E+01	3.22E+03
Toluene	108-88-3	0.0034	3.33E-04	8.00E-03	2.92E+00
Vanadium	7440-62-2	0.0023	2.25E-04	5.41E-03	1.98E+00

- All emission factors except CO, NO_x, and SO₂ are from AP-42, and are in units of pounds per million standard cubic feet (lb/MMscf). CO, NO_x, and SO₂ factors are based on BACT. The hexavalent chromium emission factor reflects the application of point source speciation data from USEPA's 2005 National Emissions Inventory (NEI) (<http://www.epa.gov/ttnchie1/net/2005inventory.html>). The point source chromium speciation database (ftp://ftp.epa.gov/EmisInventory/2005_nei/point/crspeciation01122009.zip) indicates that, for external combustion emission units firing natural gas, four percent of total chromium is hexavalent chromium.
- Emission rates based on 100 MMBtu/hr, continuous operation, and a natural gas heating value of 1,020 British thermal units per standard cubic foot (Btu/scf).

2.3.2 Lumber Dry Kilns

There will be six double-track dry kilns used to dry up to 300 million board feet of lumber per year (MMbf/yr) of the lumber produced by the sawmill, depending upon market demands. Wood species dried in the kilns will include Douglas fir, hemlock, larch, and ponderosa pine. As it dries, wood releases volatile organic compounds (VOCs) which pass to the atmosphere through vents in the roof of the kilns. Some of these compounds condense to form particulate matter (PM), and some compounds are considered TAPs. If necessary to meet production needs, the kilns could be run on a continuous basis throughout the year, though, in reality, operations are cyclical because it is a batch process. Calculated hourly and annual TAP emissions are summarized in Table 2-3. It should be noted that the maximum potential annual VOC emission rate is based on an assumption that all kiln throughput is ponderosa pine, but the majority of the dried lumber produced by the Facility is expected to be Douglas fir and hemlock.

Table 2-3. Lumber Dry Kiln Potential Toxic Air Pollutant Emissions

Pollutant	CAS #	Emission Factor ¹ (lb/Mbf)					Emission Rate ²	
		Western Hemlock	Douglas Fir	Larch	Pond. Pine	Max.	(lb/hr)	(tpy)
Acetaldehyde	75-07-0	0.113	0.057	0.057	0.113	0.113	3.87	17.0
Acrolein ³	107-02-8	0.0016	0.00065	0.00065	0.0016	0.0016	0.0548	0.240
Formaldehyde	50-00-0	0.00124	0.0010	0.0010	0.0029	0.0029	0.0993	0.352
Methanol	67-56-1	0.082	0.038	0.038	0.065	0.082	2.81	12.3

1. Emission factors for lumber dry kilns operated at temperatures greater than 200°F are from Oregon DEQ Memo (05/08/2007). Douglas fir emission factors were used for larch, because no data were available, and the species are considered similar to one another. Ponderosa pine emission factors are from Milota & Mosher, 2008, "Emissions of hazardous air pollutants from lumber drying" (Forest Products Journal Vol. 59, No. 7/8), for drying temperatures less than 200 °F; ponderosa pine is dried at less than 180 °F.
2. The annual emission rate is based on 300 MMbf/yr throughput of worst-case wood species for each pollutant, unless ponderosa pine is the worst-case wood species, in which case the annual kiln throughput was assumed to be 200 MMbf/yr. Hourly emission rate is based on an assumption of uniform operation throughout the year.
3. Hourly acrolein emissions are based on the ponderosa pine emission factor and an hourly throughput equivalent to a 300 MMbf/yr annual throughput assuming uniform operation throughout the year; annual acrolein emissions are based on a worst-case scenario in which 200 MMbf/yr of ponderosa pine and 100 MMbf/yr of western hemlock are dried.

2.3.3 Total Toxic Air Pollutant Emissions

Total TAP emission rates for the Facility are presented in Table 2-4. Maximum potential hourly, daily, or annual emission rates are provided to correspond with the averaging period associated with the Small Quantity Emission Rate (SQER) provided for each TAP in WAC 173-460-150. Table 2-4 also provides a comparison of the maximum potential TAP emission rates and the SQER for each TAP, and an indication of whether or not the maximum emission rate exceeds the SQER. As shown in Table 2-4, the calculated maximum potential emissions of eight TAPs exceeded the applicable SQER: acetaldehyde, acrolein, arsenic, cadmium, hexavalent chromium, 7,12-dimethylbenz(a)anthracene, formaldehyde, and nitrogen dioxide.

Per the definition of a SQER provided in WAC 173-460-020(7), TAPs with maximum potential emission rates that are less than the applicable SQER are not required to demonstrate compliance with the ambient impact requirement in WAC 173-460-070. However, TAPs with maximum potential emission rates that are equal to or greater than the applicable SQER must assess compliance with the ambient impact requirement using dispersion modeling as indicated in WAC 173-460-080(2)(a). The dispersion modeling is discussed in Section 4.

Table 2-4. Facility-Wide Potential Toxic Air Pollutant Emissions

Pollutant	CAS #	HAP?	Avg. Period ¹	Emission Rate (lb/avg per)				Over SQER?
				Boiler	Kilns	Total	SQER	
Acetaldehyde	75-07-0	Yes	Year	0	3.39E+04	3.39E+04	71	Yes
Acrolein	107-02-8	Yes	24-Hr	0	1.32E+00	1.32E+00	0.00789	Yes
Arsenic	7440-38-2	Yes	Year	1.72E-01	0	1.72E-01	0.0581	Yes
Benzene	71-43-2	Yes	Year	1.80E+00	0	1.80E+00	6.62	No
Benz(a)anthracene	56-55-3	Yes	Year	1.55E-03	0	1.55E-03	1.74	No
Benzo(a)pyrene	50-32-8	Yes	Year	1.03E-03	0	1.03E-03	0.174	No
Benzo(b)fluoranthene	205-99-2	Yes	Year	1.55E-03	0	1.55E-03	1.74	No
Benzo(k)fluoranthene	207-08-9	Yes	Year	1.55E-03	0	1.55E-03	1.74	No
Beryllium	7440-41-7	Yes	Year	1.03E-02	0	1.03E-02	0.08	No
Cadmium	7440-43-9	Yes	Year	9.45E-01	0	9.45E-01	0.0457	Yes
Carbon monoxide	630-08-0	No	1-Hr	3.60E+00	0	3.60E+00	50.4	No
Chromium, hexavalent	18540-29-9	Yes	Year	4.81E-02	0	4.81E-02	0.00128	Yes
Chrysene	218-01-9	Yes	Year	1.55E-03	0	1.55E-03	17.4	No
Cobalt	7440-48-4	Yes	24-Hr	1.98E-04	0	1.98E-04	0.013	No
Copper	7440-50-8	No	1-Hr	8.33E-05	0	8.33E-05	0.219	No
Dibenzo(a,h)anthracene	53-70-3	Yes	Year	1.03E-03	0	1.03E-03	0.16	No
7,12-Dimethylbenz(a)anthracene	57-97-6	No	Year	1.37E-02	0	1.37E-02	0.00271	Yes
Formaldehyde	50-00-0	Yes	Year	6.44E+01	7.04E+02	7.68E+02	32	Yes
Hexane	110-54-3	Yes	24-Hr	4.24E+00	0	4.24E+00	92	No
Indeno(1,2,3-cd)pyrene	193-39-5	Yes	Year	1.55E-03	0	1.55E-03	1.74	No
Manganese	7439-96-5	Yes	24-Hr	8.94E-04	0	8.94E-04	0.00526	No
Mercury	7439-97-6	Yes	24-Hr	6.12E-04	0	6.12E-04	0.0118	No
Methanol	67-56-1	Yes	24-Hr	0	6.74E+01	6.74E+01	526	No
3-Methylchloranthrene	56-49-5	No	Year	1.55E-03	0	1.55E-03	0.0305	No
Naphthalene	91-20-3	Yes	Year	5.24E-01	0	5.24E-01	5.64	No
Nitrogen dioxide	10102-44-0	No	1-Hr	1.10E+00	0	1.10E+00	1.03	Yes
Selenium	7782-49-2	Yes	24-Hr	5.65E-05	0	5.65E-05	2.63	No
Sulfur dioxide	7446-09-5	No	1-Hr	7.25E-01	0	7.25E-01	1.45	No
Toluene	108-88-3	Yes	24-Hr	8.00E-03	0	8.00E-03	657	No
Vanadium	7440-62-2	No	24-Hr	5.41E-03	0	5.41E-03	0.0263	No

1. The maximum 24-hour average potential to emit is calculated by assuming the maximum hourly emission rate from Table 2-2 or Table 2-3 occurs continuously for 24 hours.

2.4 Control Technology

Per WAC 173-460-060, new or modified sources that increase TAP emission rates must employ Best Available Control Technology for toxics (tBACT). The NOC application submitted to PSCAA included a BACT analysis which addressed tBACT. A summary of the submitted tBACT proposal is provided here.

For the natural gas-fired boiler, the following was proposed as BACT:

- VOC: 0.005 lb/MMBtu, achieved by employing good combustion practices;
- PM: Use of pipeline natural gas and good combustion practices;
- SO₂: Use of pipeline natural gas;
- NO₂: 0.011 lb/MMBtu, achieved by using an ultra-low NO_x burner; and
- CO: 0.036 lb/MMBtu, achieved by employing good combustion practices.

TAP compounds emitted by a natural gas-fired boiler are, in general, either volatiles (i.e., VOCs) or particles (i.e., PM). The proposed BACT for VOC and PM were also proposed to be tBACT for VOC and PM TAPs, respectively. tBACT for TAPs that contain chlorine (e.g., hydrogen chloride) and sulfur (e.g., sulfuric acid) was proposed to be the same as BACT proposed for SO₂. Nitrogen dioxide (NO₂) and carbon monoxide (CO) are TAPs as well as criteria pollutants, so the tBACT proposals for those two pollutants were identical to the BACT proposals.

In the submitted permit application, SPI proposed that BACT and tBACT for the lumber dry kilns proposed for the Frederickson Facility is use of a computerized kiln management system, which also reduces emissions from the boiler by minimizing demand.

PSCAA concurs with SPI's tBACT proposal, which is reflected in the draft Order of Approval issued by PSCAA.

As stated in the permit application, the Facility will be a "major" source of Hazardous Air Pollutants (HAPs) under the National Emission Standards for Hazardous Air Pollutant (NESHAP) program, because it is expected to emit at least one HAP (i.e., acetaldehyde and methanol) at an annual rate greater than 10 tons per year (tpy) and facility-wide HAP emissions will exceed an annual rate of 25 tpy. The NESHAP rules promulgated under Section 112 generally specify the Maximum Achievable Control Technology (MACT) that must be applied for a given industry category. Consequently, these rules are often called MACT standards.

The package boiler will be a new unit with a maximum design heat input greater than or equal to 10 MMBtu/hr, and will combust only pipeline natural gas. As a result, 40 CFR Part 63, Subpart DDDDD (Industrial, Commercial, and Institutional Boilers and Process Heaters) will require the proposed boiler to have an annual tune-up, but there are no applicable emission limits. The boiler will also be subject to initial notification, recordkeeping, and reporting requirements.

Although the proposed Facility will not manufacture plywood or composite wood products, 40 CFR Part 63, Subpart DDDD applies to lumber dry kilns located at any facility. According to 40 CFR 63.2252, the only MACT requirement that applies to lumber kilns is the initial notification

requirement in 40 CFR 63.9(b). Pursuant to 40 CFR 63.9(b)(iii), the permit application submitted to PSCAA will serve as the initial notification for the lumber dry kilns.

3 Hazard Identification

As noted above, the maximum potential emission rates of eight TAPs exceed the assigned SQER, and three of those were predicted by the dispersion modeling to exceed the assigned ASIL. The TAPs which exceeded the ASILs (acetaldehyde, formaldehyde, and acrolein), as well as the TAPs that exceeded only the SQER which have similar health effects (arsenic, cadmium, hexavalent chromium, 7,12-dimethylbenz(a)anthracene and nitrogen dioxide), are assessed in the 2nd tier analysis. A summary of the potential effects of each TAP that is expected to exceed the assigned SQER is presented in Table 3-1. The hazard quotient target, which is the organ or organ system that is the target of the health effects, is also provided for each chemical.

This report presents the adverse health effects, physical properties, environmental fate and transport, and general health effects associated with the TAPs that exceeded the ASILs: acetaldehyde, acrolein, and formaldehyde. Principal sources of 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.

Table 3-1. Potential Effects of Chemicals that Exceed the SQER

Toxic Air Pollutant	CAS #	Critical Effects for Hazard Quotient
Acetaldehyde	75-07-0	Sensory irritation, redness, and swelling of the eye; bronchoconstriction; degenerative, inflammatory, and hyperplastic changes of the nasal mucosa; nasal and laryngeal tumors and cancer by hyperplasia mechanism Hazard quotient targets: nose and throat (nasopharynx), eye, and bronchus
Acrolein	107-02-8	Hazard index targets: eye and entire respiratory tract
Arsenic	7440-38-2	Mutagenic effects likely to result in progression of initiated lung cancers. Hazard quotient targets: skin, cardiovascular system, nervous system, development
Cadmium	7440-43-9	Reduced forced vital capacity and reduction in peak expiratory flow rate. Weak association with lung cancer—possible interference with spindle formation. Hazard quotient targets: kidney and respiratory tract
Chromium, hexavalent	18540-29-9	Hematologic effects; perforations and ulcerations of the septum; nasal itching and soreness; bronchitis; pneumonia; decreased pulmonary function and asthma; lung cancer Hazard quotient targets: blood, respiratory tract, nose
7,12-Dimethylbenz(a)anthracene	57-97-6	Photosensitivity and irritation of the eye; respiratory irritation with cough and bronchitis; leukoplakia; "coal tar warts" (precancerous lesions enhanced by UV light exposure), erythema, dermal burns, dermal photosensitivity, acneiform lesions, dermal irritation; mild hepatotoxicity or mild nephrotoxicity; hematuria; skin, bladder, lung, and possibly gastrointestinal tract cancers. Hazard quotient targets: respiratory tract, gastrointestinal system, liver, kidney, bladder, blood, skin, immune system, reproductive system
Formaldehyde	50-00-0	Irritation of mucous membranes of eyes, nose, and throat; inflammation; epithelial degeneration; respiratory epithelial hypertrophy; and squamous metaplasia. Acute high exposure may lead to eye, nose, throat, and respiratory tract irritation, nasal obstruction, pulmonary edema, and dyspnea. Prolonged or repeated exposures are associated with allergic sensitization, cough, wheeze, dyspnea, histopathological changes in respiratory epithelium, and decrements in lung function. Chronic exposure in children, especially those with asthma, is more likely to induce symptoms and impair pulmonary functioning than in adults. Nasopharyngeal and respiratory tract cancer; possibly brain cancer and leukemia. Hazard quotient targets: nasopharynx, respiratory tract
Nitrogen dioxide (NO ₂)	10102-44-0	Reacts with water in the respiratory tract to form nitric acid, which is a corrosive irritant. It impairs lung function and causes an array of respiratory problems including airway inflammation in healthy people, and increased symptoms in people with asthma. Children, elderly, and asthmatic people are particularly sensitive. It probably also increases allergic responses to inhaled pollens. Hazard quotient target: respiratory tract

3.1 Potential Effects of Chemicals that Exceed the ASIL

Depending on exposure levels, the three TAPs that exceed ASIL concentrations, i.e., acetaldehyde, acrolein, and formaldehyde, can adversely affect the nose and throat (nasopharynx), the eyes, and the entire respiratory tract, including the bronchi. Additionally, acetaldehyde exposure may cause nasal and laryngeal cancer, and formaldehyde may cause nasopharyngeal and respiratory tract cancers. The primary acute effects of human exposure to acetaldehyde in air consist of irritation to the eyes, skin, and respiratory tract.¹ Asthmatics exposed to acetaldehyde may experience a decrease in lung function due to bronchoconstriction.

There is little information regarding health outcomes in humans related to long-term exposure to acetaldehyde. In animals, chronic inhalation exposure to acetaldehyde has produced changes in the mucus membranes of the nose and trachea, growth retardation, slight anemia, and increased kidney weight. EPA derived a toxicity value based on the degeneration of a layer of cells lining the tissue responsible for smell in the noses (olfactory epithelium) of rats.² Animal studies involving inhalation of acetaldehyde have shown an increased rate of nasal tumors in rats and laryngeal tumors in hamsters. EPA has classified acetaldehyde as a Group B2, probable human carcinogen.

Low levels of formaldehyde can cause irritation of the eyes, nose, throat, and skin. It is possible that people with asthma exposed to formaldehyde can experience respiratory symptoms such as wheezing, shortness of breath, and reduced pulmonary function consistent with bronchoconstriction.³ At concentrations that typically occur in ambient air, effects occur in tissues where formaldehyde enters the body (i.e., nose or mouth). At higher levels, coughing, wheezing, bronchitis, nasal obstruction, pulmonary edema, choking, dyspnea, and chest tightness may occur.

People chronically exposed to formaldehyde by inhalation have experienced respiratory symptoms and eye, nose, and throat irritation. Animal studies have reported effects on the nasal respiratory epithelium and lesions in the respiratory system from chronic inhalation exposure to formaldehyde. Some studies of people exposed to formaldehyde in workplace air found more cases of cancer of the nose and throat than expected, but these workers may have been exposed to multiple different chemicals, so it is not clear if formaldehyde was the chemical that caused this increased rate. In animal studies, rats exposed to high levels of formaldehyde in air developed cancer in a type of epithelial cell in the nose (nasal squamous cell carcinoma). The United States Department of Health and Human Services has determined that formaldehyde may reasonably be anticipated to be a carcinogen.⁴ EPA has classified formaldehyde as a Group B1, probable human carcinogen.

Acrolein is an irritant to skin and mucous membranes. Effects of acrolein typically occur at the point of exposure (i.e., nasal passages, eyes) and upper respiratory tract. Short-term exposure

¹ http://www.arb.ca.gov/toxics/id/summary/acetaldehyde_b.pdf

² <http://www.epa.gov/ncea/iris/subst/0290.htm>

³ http://www.oehha.ca.gov/air/toxic_contaminants/pdf_zip/formaldehyde_112508.pdf

⁴ <http://www.atsdr.cdc.gov/tfacts111.html#bookmark06>

to acrolein can cause eye and nasal irritation at relatively low concentrations (< 1ppm [≤ 2.3 mg/m₃]) in air.⁵ Higher concentrations may also irritate the entire respiratory tract. Water soluble fine particulates may potentiate the irritancy of acrolein. Accidental exposures to extremely high levels of acrolein result in high fever, dyspnea, coughing, foam expectoration, cyanosis, pulmonary edema, and death.⁶ Animals exposed to higher acrolein concentrations showed signs of lesions in the respiratory tract and respiratory distress. These effects became more severe with increasing concentrations. At higher levels, respiratory distress resulted in death.

There are no available studies of humans exposed to acrolein over long periods. Longer-term studies in laboratory animals at higher concentrations have demonstrated severe nasal lesions as well as pronounced adverse effects on lung function leading to lethality. Studies indicated that rats were the most sensitive species. The potential carcinogenicity of acrolein cannot be determined because the existing data are inadequate for an assessment of human carcinogenic potential for either the oral or the inhalation route of exposure.

3.2 Atmospheric Fate

Generally, acetaldehyde, formaldehyde, and acrolein are not persistent in air. They react with other chemicals in air (mainly sunlight-derived radicals). The estimated half-life for the reaction of acetaldehyde with the hydroxyl radical produced by ultra violet light is 6.2 hours. Most formaldehyde in the air also breaks down during the day. The breakdown products of formaldehyde in air include formic acid and carbon monoxide. In air, acrolein is broken down by chemicals generated in sunlight producing carbon monoxide, formaldehyde, and glycolaldehyde. Acrolein also reacts with nitrogen oxides to form peroxyacetyl nitrate and nitric acid. The half-life for the reaction of acrolein with the hydroxyl radical is 15 to 20 hours.⁷

3.3 Terrestrial Fate

None of the chemicals are likely to build up in soil if emitted in the small amounts estimated by SPI. Acetaldehyde will volatilize rapidly in surface soils.⁸ Formaldehyde is biodegraded in soil in a relatively short time.⁹ Acrolein can be mobile in soil, but a large portion is expected to volatilize or be broken down by microorganisms or other reactive processes.¹⁰

3.4 Aquatic Fate

According to Facility estimates, the chemicals are unlikely to accumulate in aquatic environments. Acetaldehyde dissolves in water, but will not reside long in surface water as it either will volatilize or be broken down by microbes. A degradation half-life of 9.3 hours has been reported as typical for rivers.¹¹ Formaldehyde dissolves easily in water, but it does not reside long in water and is not commonly found in drinking water supplies. Acrolein dissolves readily in water but levels are reduced through volatilization, aerobic biodegradation, and

⁵ http://www.oehha.ca.gov/air/toxic_contaminants/pdf_zip/acrolein_112508.pdf

⁶ <http://www.atsdr.cdc.gov/toxprofiles/tp124.html>

⁷ <http://www.atsdr.cdc.gov/toxprofiles/tp124-c6.pdf>

⁸ <http://www.inchem.org/documents/ehc/ehc/ehc167.htm>

⁹ <http://www.atsdr.cdc.gov/toxprofiles/tp111-c5.pdf>

¹⁰ <http://www.atsdr.cdc.gov/toxprofiles/tp124-c6.pdf>

¹¹ http://www.epa.gov/chemfact/s_acetal.txt

hydration to other chemicals that subsequently biodegrade. Degradation half-lives are less than 1 to 3 days for small amounts of acrolein in surface water.

4 Pollutant Concentration Calculations

4.1 Modeling methodology

Air dispersion modeling is frequently used to provide 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.

4.1.1 Model Selection

Regulatory modeling techniques were reviewed to select the most appropriate air quality dispersion model to simulate dispersion of air pollutant emissions attributable to the proposed project. AERMOD, the preferred model in the U.S. Environmental Protection Agency's (USEPA's) "Guideline on Air Quality Models" (codified as Appendix W to 40 CFR Part 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 2nd Tier guidance document.¹²

4.1.2 Modeling Procedures

AERMOD was applied using regulatory defaults and the options and data discussed in this section.

4.1.2.1 Setup and Application

The most up-to-date version of AERMOD (Version 13350) available was applied using the default 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 for modeling purposes and rural dispersion coefficients were used.

4.1.2.2 Averaging Periods

The TAPs listed in WAC 173-460-150 have assigned averaging periods: 1-hour, 24-hour, or annual. Of the eight TAPs calculated to exceed the assigned SQER, all are assigned an annual averaging period, except acrolein, which has a 24-hour averaging period, and NO₂, which has a 1-hour averaging period. AERMOD was executed to provide ambient concentrations on those bases. However, based on the different characteristics of potentially exposed receptors and the possibility for acute and chronic effects, AERMOD was also configured to provide acute (1-hour, 8-hour, and 24-hour) and chronic (annual) results for all eight TAPs.

4.1.3 Terrain Elevation Data and Receptor Network

The 10-km-by-10-km domain used for the modeling simulations is shown in Figure 2-1. Terrain elevations for receptors, as well as the base elevations of onsite structures and emission units, were prepared using available data from the National Elevation Dataset (NED) developed by the United States Geological Survey (USGS); these data have a horizontal spatial resolution of approximately 10 m. The elevation and hill height scale for each receptor were determined using the AERMOD terrain preprocessor, AERMAP (version 11103). All receptor locations are

¹² Department of Ecology, "Guidance Document: First, Second, and Third Tier Review of Toxic Air Pollution Sources (Chapter 173-460 WAC)." Publication Number 08-02-025, revised September 2013.

in Universal Transverse Mercator (UTM) coordinates using the spatial reference of NAD 83, Zone 10.

Receptors spaced 500 meters (m) apart were placed throughout the modeling domain. Nested grids of receptors with 25-m, 50-m, and 200-m spacing were within 1.8-km, 3-km, and 5-km square areas, respectively, with the Facility at the center of each. Receptors were also located at 10-m intervals along the perimeter of the building in which the Facility is located.

Ecology's 2nd Tier Guidance recommends using receptors spaced 10 m apart to ensure that sampling error does not reduce the maximum computed concentration by more than 10 percent. Additional receptor grids with 10-m spacing were added in the areas surrounding the maximum ambient impact locations. Addition of the 10-m spacing receptors had little effect on the magnitude and location of the maximum concentrations predicted by the modeling. The maximum effect was to increase a predicted maximum concentration by 0.2 percent, and to move the location of the maximum concentration by less than a meter.

The final receptor locations, including the added 10-m receptors, are shown in Figure 4-1.

4.1.4 Meteorological Data

ENVIRON conducted a survey of available meteorological data for use in the modeling simulations. A representative five-year data set was prepared using available surface and upper air data for the period 2008 through 2012. Surface meteorology data from the National Weather Service (NWS) Automated Surface Observing System (ASOS) station at McChord Field, at Joint Base Lewis-McChord in Pierce County, Washington, and upper air data collected at the NWS station in Quillayute, Washington were used. A windrose summarizing the McChord Field wind speed and wind direction data over the five-year period is provided in Figure 4-2.

Additional meteorological variables and geophysical parameters are required for use in the AERMOD dispersion modeling analysis to estimate the surface energy fluxes and construct boundary layer profiles. Surface characteristics including albedo, Bowen ratio, and surface roughness length were determined for the area surrounding the McChord Field meteorological station using the AERMET surface characteristic preprocessor, AERSURFACE (Version 08009), and the USGS 1992 National Land Cover (NLCD92) land use data set.¹³ The NLCD92 data set used in the analysis has a 30 m mesh size and 21 land use categories. Seasonal surface parameters were determined using AERSURFACE according to the EPA's guidance.¹⁴

Seasonal albedo and Bowen ratio values were based on averaging over a 10-km by 10-km region centered on the McChord Field meteorological station. An unweighted arithmetic average was used for calculating seasonal albedo; and an unweighted geometric average was used for calculating seasonal Bowen ratio. Seasonal surface roughness values were calculated for 12 30 degree sectors within 1 kilometer of the McChord Field meteorological station. An inverse-

¹³ The USGS NLCD92 data set is described and can be accessed at <http://landcover.usgs.gov/natl/landcover.php>.

¹⁴ The AERMOD Implementation Guide (EPA, 2009) and the AERSURFACE User's Guide (EPA-454/B-08-001, January 2008).

distance weighted geometric average was used to calculate seasonal surface roughness length values for each of the 12 sectors.

The AERSURFACE input file requires the user to provide additional location and climatological information regarding the primary meteorological station (in this case, McChord Field). The following information was used to process seasonal surface parameters for the meteorological station:

- The site was assumed to not have continuous snow cover most of the winter. There is typically little or no snowfall in the area, and the annual average total snowfall at the McMillin Reservoir NWS cooperative network meteorological station (the station nearest to McChord Field) is 8.7 inches.
- The site is located at an airport.
- The site was assumed to not be located in an arid region.
- The annual average precipitation at McChord Field from 2008 through 2012 was between the 30th and 70th percentiles of the annual precipitation at McMillin Reservoir over the past 30 years (average surface moisture conditions).¹⁵

The land-use processing domains are shown in Figure 4-3. Table 4-1 presents the AERSURFACE calculated seasonal albedo, Bowen ratio, and surface roughness length values for area surrounding the McChord Field meteorological station.

The EPA meteorological program AERMET (Version 11059) was used to combine the surface meteorological observations collected by the McChord Field meteorological station with the twice-daily upper air soundings from Quillayute, Washington and to calculate the meteorological variables and profiles required by AERMOD. Following recommendations in the March 8, 2013 EPA memorandum regarding the use of ASOS metrological data in AERMOD dispersion modeling, AERMINUTE (version 11325) was used to resolve calm and variable wind conditions in the standard ASOS data using 1-minute wind speed and wind direction data gathered at McChord Field over the concurrent time period, and a minimum wind speed threshold of 0.5 meters per second (m/s) was used when executing AERMET.

¹⁵ Western U.S. Climate Historical Summaries can be accessed at <http://www.wrcc.dri.edu/Climsum.html>

Table 4-1. McChord Field Surface Characteristics

AERSURFACE Sector	Albedo	Bowen Ratio	Surface Roughness Length (meters)	Albedo	Bowen Ratio	Surface Roughness Length (meters)
	Winter			Spring		
1	0.15	0.5	0.052	0.14	0.41	0.063
2	0.15	0.5	0.05	0.14	0.41	0.055
3	0.15	0.5	0.052	0.14	0.41	0.058
4	0.15	0.5	0.054	0.14	0.41	0.062
5	0.15	0.5	0.043	0.14	0.41	0.056
6	0.15	0.5	0.036	0.14	0.41	0.043
7	0.15	0.5	0.163	0.14	0.41	0.224
8	0.15	0.5	0.442	0.14	0.41	0.607
9	0.15	0.5	0.372	0.14	0.41	0.497
10	0.15	0.5	0.399	0.14	0.41	0.536
11	0.15	0.5	0.315	0.14	0.41	0.431
12	0.15	0.5	0.151	0.14	0.41	0.182
	Summer			Fall		
1	0.14	0.33	0.071	0.14	0.5	0.066
2	0.14	0.33	0.059	0.14	0.5	0.056
3	0.14	0.33	0.063	0.14	0.5	0.059
4	0.14	0.33	0.068	0.14	0.5	0.063
5	0.14	0.33	0.067	0.14	0.5	0.059
6	0.14	0.33	0.049	0.14	0.5	0.044
7	0.14	0.33	0.27	0.14	0.5	0.254
8	0.14	0.33	0.722	0.14	0.5	0.713
9	0.14	0.33	0.562	0.14	0.5	0.557
10	0.14	0.33	0.604	0.14	0.5	0.597
11	0.14	0.33	0.482	0.14	0.5	0.475
12	0.14	0.33	0.201	0.14	0.5	0.196

4.1.5 Emission Unit Characterization

The package boiler and lumber dry kilns will be the exclusive sources of the TAPs with maximum emission rates expected to exceed the applicable SQERs. The locations of the boiler stack and the kiln vents are shown in Figure 2-2. The parameters used to characterize emissions from these point sources in the modeling are summarized in Table 4-2.

Table 4-2. Emission Release Parameters

Source	Height (ft / m)	Temperature (°F / K)	Exit Velocity (ft/s / m/s)	Inside Diameter (ft / m)
Package Boiler Stack	65.0 / 19.8	448 / 504	35.2 / 10.7	3.50 / 1.07
Lumber Dry Kiln Vents	20.0 / 6.1	210 / 372	5.0 / 1.5	2.63 / 0.80

Downwash algorithms incorporated into AERMOD account for the plume dispersion effects of the aerodynamic wakes and eddies produced by buildings and structures. In addition to providing a Good Engineering Practice (GEP) evaluation, the BPIP-PRIME program was used to determine direction-specific downwash parameters for each point source. Using the output from BPIP-PRIME, AERMOD calculates fields of turbulence intensity, wind speed, and slopes of the mean streamlines as a function of projected structure shape. AERMOD also uses a numerical plume rise model to determine the change in plume centerline location and the rate of plume dispersion with downwind distance. Concentrations are predicted in both the near and far wake regions, with the plume mass captured by the near wake treated separately from the uncaptured primary plume, and re-emitted to the far wake as a volume source. The locations and dimensions of each on-site structure shown in Figure 2-2 were provided to BPIP-PRIME.

4.2 Modeling Results

To evaluate ambient concentrations (i.e., impacts on air quality) attributable to the Facility 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 results for the eight TAPs with the potential to exceed the assigned SQERs are presented in Table 4-3.

Table 4-3. Maximum Predicted Toxic Air Pollutant Concentrations

Toxic Air Pollutant	CAS #	Averaging Period	Maximum Concentration ($\mu\text{g}/\text{m}^3$)	ASIL ($\mu\text{g}/\text{m}^3$)	Over ASIL?
Acetaldehyde	75-07-0	Annual	7.72	0.37	Yes
Acrolein	107-02-8	24-hr	1.04	0.06	Yes
Arsenic	7440-38-2	Annual	0.0000154	0.000303	No
Cadmium	7440-43-9	Annual	0.0000849	0.000238	No
Chromium, hexavalent	18540-29-9	Annual	0.00000432	0.00000667	No
7,12-Dimethylbenz(a)anthracene	57-97-6	Annual	0.00000123	0.0000141	No
Formaldehyde	50-00-0	Annual	0.200	0.167	Yes
Nitrogen dioxide (NO ₂)	10102-44-0	1-hr	17.5	470	No

The maximum concentration receptor is the same for all three scenarios: a receptor located along the perimeter of the Facility. Contour plots showing the spatial variation of the annual and 24-hour average acetaldehyde, acrolein, and formaldehyde concentrations throughout the modeling domain are shown in Figures 4-4 through 4-9, and in the area near the Facility in Figures 4-10 through 4-15. The Facility perimeter receptor locations are spaced at 10-m intervals along the fence line; to reduce sampling error, the model simulations were repeated following the addition of two 10-m spacing receptor grids in the areas surrounding the locations of the maximum off-site concentrations. The locations and magnitudes of the maximum concentrations were unchanged following the addition of the 10-m spacing receptor grid.

4.3 Background Concentration

The US 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 2005, and the total modeled acetaldehyde, acrolein, arsenic, cadmium, chromium, and formaldehyde concentrations in the census tract in which the Facility is located are presented in Table 4-4. The 2005 NATA did not include 7,12-dimethylbenz(a)anthracene or NO₂.

Table 4-4. NATA 2005 Predicted Toxic Air Pollutant Concentrations

Toxic Air Pollutant	Annual Average Concentration ($\mu\text{g}/\text{m}^3$)
Acetaldehyde	1.35
Acrolein	0.0742
Arsenic Compounds (Inorganic, including Arsine)	0.000152
Cadmium Compounds	0.0000441
Chromium Compounds	0.0000980
Formaldehyde	1.52

SPI is unaware of any ambient monitoring studies involving the TAPs of concern that have been conducted in the immediate vicinity of the proposed Facility location. However, ambient concentrations of acetaldehyde and formaldehyde have been measured at several sites in western Washington. The station names, years monitoring occurred, mean monitored concentrations, and NATA 2005 concentration for the census tract in which the station is or was located are provided for acetaldehyde and formaldehyde in Tables 4-5 and 4-6.

Table 4-5. Monitored Acetaldehyde Concentrations in Western Washington

Site	Timeframe	No. of Samples	Monitor Mean ($\mu\text{g}/\text{m}^3$)	NATA 2005 ($\mu\text{g}/\text{m}^3$)	Monitor Mean/NATA Ratio
Vancouver - Blairmont Dr	1995-1996	20	2.66	2.71	0.98
Bellingham	1995-1996	36	11.56	1.12	10.33
Vancouver - 4th PI Blvd E	2001	58	2.02	1.92	1.05
Issaquah - Lake Sammamish	2001-2002	59	1.27	1.46	0.87
Seatac North	2001-2002	63	1.35	1.88	0.72
Lake Forest Park Towne Center	2001-2002	119	1.46	1.60	0.92
Georgetown	2000-2003	163	1.56	1.92	0.81
Seattle - 14th Ave. N.E.	2001-2002	56	1.14	1.73	0.66
Vancouver Kauffman & W 27th	2004-2006	57	1.38	2.12	0.65
Longview	2004-2005	59	1.69	2.13	0.79
Seattle - Duwamish	2008-2009	57	1.43	2.21	0.65
Tacoma - L Street	2008-2009	59	0.97	1.61	0.61
Tacoma - Alexander Ave	2008-2009	59	1.36	1.93	0.71
Longview - St Helens	2009	14	1.58	1.71	0.93
Seattle - Beacon Hill	2000-2012	735	1.23	1.62	0.76

Table 4-6. Monitored Formaldehyde Concentrations in Western Washington

Site	Timeframe	No. of Samples	Monitor Mean ($\mu\text{g}/\text{m}^3$)	NATA 2005 ($\mu\text{g}/\text{m}^3$)	Monitor Mean/NATA Ratio
Vancouver - Blairmont Dr	1995-1996	20	1.86	3.30	0.56
Bellingham	1995-1996	36	15.21	1.37	11.14
Vancouver - 4th PI Blvd E	2001	58	2.35	2.43	0.97
Issaquah - Lake Sammamish	2001-2002	59	1.04	1.68	0.62
Seatac North	2001-2002	63	1.33	2.54	0.53
Lake Forest Park Towne Center	2001-2002	118	1.22	1.88	0.65
Georgetown	2000-2003	166	2.09	2.63	0.80
Seattle - 14th Ave. N.E.	2001-2002	54	1.26	2.18	0.58
Vancouver Kauffman & W 27th	2004-2006	58	1.90	2.40	0.79
Longview	2004-2005	59	1.77	1.45	1.22
Seattle - Duwamish	2008-2009	14	1.61	1.41	1.14
Tacoma - L Street	2008-2009	57	2.80	2.99	0.94
Tacoma - Alexander Ave	2008-2009	59	1.46	1.98	0.74
Longview - St Helens	2009	59	1.96	2.41	0.81
Seattle - Beacon Hill	2000-2012	732	1.32	1.94	0.68

As shown in Tables 4-5 and 4-6, almost all the measured concentrations are within a factor of two of the NATA 2005 estimates for the census tract in which the station is or was located (the Bellingham station being the only exception). In the absence of site-specific monitoring data, Ecology typically concurs that use of NATA 2005 estimates to quantify background concentrations is appropriate for this analysis.

Monitored acrolein concentrations were not obtained for comparison to the NATA 2005 concentrations, because the data are considered unreliable and should not be used. Acrolein is highly reactive, making it one of the most difficult chemicals to measure. An EPA study has raised questions concerning the consistency and reliability of acrolein monitoring results; these questions have not been resolved. The NATA 2005 acrolein concentration for the census tract in which the proposed Facility is to be located was used as the acrolein background concentration for this analysis.

The NATA 2005 concentrations for arsenic, cadmium, and chromium concentrations were used as background without comparison to measured concentrations. It should be noted that the NATA 2005 concentration for chromium is total chromium rather than speciated hexavalent

chromium. Anthropogenic sources make up approximately 60 to 70 percent of all atmospheric chromium, of which hexavalent chromium typically comprises one third¹⁶.

The Northwest International Air Quality Environmental Science and Technology (NW-AIRQUEST) Consortium provides an online tool¹⁷ that interpolates modeled and monitored criteria pollutant concentrations from 2009 through 2011 to obtain pollutant concentration estimates at a given location. For the facility location (UTM zone 10 coordinates 546930 easting, 5213480 northing), the tool provided 1-hour and annual average NO₂ concentrations of 51 and 6.2 parts per billion (ppb), respectively. These concentrations were converted to a mass-per-unit-volume basis using a molar volume of 24.46 liters per mole: 95.9 µg/m³ for the 1-hour average, and 11.7 µg/m³ for the annual average.

¹⁶ ATSDR. 2012. Toxicological Profile for Chromium. <http://www.atsdr.cdc.gov/toxprofiles/tp7.pdf>

¹⁷ <http://lar.wsu.edu/nw-airquest/lookup.html>

5 Identification of Potentially Exposed Populations

The HIA evaluates potential airborne exposure to modeled acetaldehyde, acrolein, arsenic, cadmium, hexavalent chromium, 7,12-dimethylbenz(a)anthracene, formaldehyde, and nitrogen dioxide concentrations attributable to the Facility. The 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) locations are identified in Figure 5-1 and 5-2 and hazards are quantified at these receptor locations in the Risk Characterization. The MIRR is the location of a current resident. The MICR is the location of a current commercial facility.

In addition, a maximally impacted boundary receptor (MIBR) is identified in Figure 5-1 and 5-2. This location is for receptors that experience the highest concentration of acetaldehyde, acrolein, and formaldehyde along the Facility perimeter, which serves as the boundary for publicly-accessible land. Potential receptors that may be periodically present around the perimeter of the Facility include employees or customers of the Facility or adjacent businesses.

For most TAP concentrations and averaging periods, the overall maximally impacted receptor (MIR) and the MIBR are the same. In cases where they differ, the distance between the two is less than 10 m, and the difference in concentration is less than 0.5 percent. The point of maximum impact may not correspond to an existing residential or commercial location, but impacts are quantified to provide an upper-bound estimate of potential exposures within the vicinity of the Facility.

5.2 Sensitive Populations

For the purpose of this HIA, sensitive populations are identified as children, the infirm, and elderly persons. These populations may be more sensitive to the effects of TAPs. The nearest identified sensitive receptors are listed in Table 5-1, and the locations relative to the Facility are presented in Figure 5-1. All of these locations are farther from the Facility than the MIR, MIBR, MIRR, and MICR.

Table 5-1. Nearest Sensitive Receptors

Type of Receptor	Name	Address	Distance (km / mi)
Place of Worship	Spanaway Christian Center	2201 215 th Street E Spanaway, WA 98387	1.12 / 0.69
	Elk Plain Community Church	4115 224 th Street E Spanaway, WA 98387	1.57 / 0.98
Daycare/Preschool	Hugs, Tugs & Luvs Childcare & Preschool	4308 208 th Street E Spanaway, WA 98387	0.56 / 0.35
	Child's Time, Inc.	21620 38 th Avenue E Spanaway, WA 98387	0.89 / 0.55
Convalescent Home	Emerald Care Center	23809 46 th Avenue E Spanaway, WA 98387	3.24 / 2.01
	McGee's Guest Home	21520 82 nd Avenue E Spanaway, WA 98387	4.43 / 2.75
Medical Facility	Community Health Care	134 188 th Street S Spanaway, WA 98387	3.76 / 2.34
	Spanaway Multicare Clinic	225 176 th Street S Spanaway, WA 98387	4.48 / 2.78
School	Shining Mountain Elementary	21615 38 th Avenue E Spanaway, WA 98387	0.88 / 0.55
	Bethel Middle School	22001 38 th Avenue E Spanaway, WA 98387	1.08 / 0.67

6 Exposure Assessment

The exposure assessment describes the routes and manner by which receptors identified in the previous section may be exposed to acetaldehyde, acrolein, and formaldehyde emitted from the Facility. Concentrations to which receptor populations may be exposed and key exposure assumptions are also 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 Facility emissions also may occur indirectly, through incidental ingestion of and skin contact with emissions deposited on area surface soils. However, indirect exposures through ingestion and skin contact pathways are not considered significant in comparison with the direct inhalation pathway. Ecology's 2nd Tier guidance document¹⁸ references California Air Toxic Hot Spots Program guidance¹⁹ to assess the need for consideration of these and other indirect exposure pathways in addition to consideration of inhalation exposure. The TAPs which exceed their ASIL (acetaldehyde, acrolein, and formaldehyde) 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, etc.) are those that are persistent and bio-accumulative. Acetaldehyde, acrolein, and formaldehyde do not bioaccumulate, 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 acetaldehyde, acrolein, and formaldehyde and the five other TAPs that exceed the SQER are estimated for each type of the identified receptor population (e.g., MIRR, MICR, MIR, and MIBR). Modeled receptors were placed at or very close to the locations of existing receptors and sensitive populations, and the maximum or average of modeled concentrations at these locations was applied to the exposure calculations.

ECs were modeled (see Section 4) for maximum annual average concentrations to represent chronic exposures. For acute exposures, the ECs are represented by the maximum modeled 1-hour, 8-hour, and 24-hour air concentrations. Typically chronic exposures are relevant to the MIRR and acute exposures are relevant to the MICR and MIBR. However, for each receptor, chronic and acute exposure concentrations were modeled. For chromium, only annual concentrations were modeled because toxicity values were not available for acute exposures. Modeling results are presented in Tables 6-1 and 6-2.

¹⁸ Department of Ecology. 2013. Guidance Document: First, Second, and Third Tier Review of Toxic Air Pollution Sources (Chapter 173-460 WAC). Publication Number 08-02-025, revised September 2013.

¹⁹ Office of Environmental Health Hazard Assessment (OEHHA). 2003. Air Toxics Hot Spots Program Risk Assessment Guidelines: The Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments. California Environmental Protection Agency. August 2003.
http://www.oehha.ca.gov/air/hot_spots/pdf/HRAguidefinal.pdf

Table 6-1: Exposure Concentrations for the MIBR and MIR

TAP	MIBR			MIR		
	Period	Concentration (µg/m ³)	Coordinates	Period	Concentration (µg/m ³)	Coordinates
Acetaldehyde	1-hr	284	546752, 5212992	1-hr	284.5	546752, 5212992
	8-hr	95.5	546528, 5213351	8-hr	95.5	546528, 5213351
	24-hr	70.9	546722, 5212992	24-hr	71.0	546722, 5212992
	Annual	7.72	546722, 5212992	Annual	7.74	546722, 5212992
Acrolein	1-hr	4.03	546752, 5212992	1-hr	4.03	546752, 5212992
	8-hr	1.35	546528, 5213351	8-hr	1.35	546528, 5213351
	24-hr	1.00	546722, 5212992	24-hr	1.00	546722, 5212992
	Annual	0.109	546722, 5212992	Annual	0.110	546722, 5212992
Arsenic	1-hr	3.12E-04	546927, 5213555	1-hr	3.12E-04	546927, 5213555
	8-hr	1.53E-04	546767, 5213556	8-hr	1.53E-04	546767, 5213556
	24-hr	8.61E-05	546772, 5212991	24-hr	8.62E-05	546772, 5212982
	Annual	1.54E-05	546807, 5213556	Annual	1.54E-05	546807, 5213556
Cadmium	1-hr	1.72E-03	546927, 5213555	1-hr	1.72E-03	546927, 5213555
	8-hr	8.40E-04	546767, 5213556	8-hr	8.40E-04	546767, 5213556
	24-hr	4.74E-04	546772, 5212991	24-hr	4.74E-04	546772, 5212982
	Annual	8.49E-05	546807, 5213556	Annual	8.49E-05	546807, 5213556
Chromium (VI)	Annual	4.32E-06	546807, 5213556	Annual	4.32E-06	546807, 5213556
7,12-Dimethylbenz(a)anthracene	1-hr	2.50E-05	546927, 5213555	1-hr	2.50E-05	546927, 5213555
	8-hr	1.22E-05	546767, 5213556	8-hr	1.22E-05	546767, 5213556
	24-hr	6.89E-06	546772, 5212991	24-hr	6.89E-06	546772, 5212982
	Annual	1.23E-06	546807, 5213556	Annual	1.23E-06	546807, 5213556
Formaldehyde	1-hr	7.30	546752, 5212992	1-hr	7.30	546752, 5212992
	8-hr	2.45	546528, 5213351	8-hr	2.45	546528, 5213351
	24-hr	1.83	546722, 5212992	24-hr	1.83	546722, 5212992
	Annual	0.200	546722, 5212992	Annual	0.200	546722, 5212992
Nitrogen Dioxide	1-hr	17.5	546927, 5213555	1-hr	17.5	546927, 5213555
	Annual	0.866	546807, 5213556	Annual	0.866	546807, 5213556

Table 6-2: Exposure Concentrations for the MIRR and MICR

TAP	MIRR			MICR		
	Period	Concentration (µg/m ³)	Coordinates	Period	Concentration (µg/m ³)	Coordinates
Acetaldehyde	1-hr	227	546812, 5212932	1-hr	107	546850, 5213850
	8-hr	59.8	546812, 5212922	8-hr	32.1	546875, 5213850
	24-hr	29.2	546822, 5212932	24-hr	18.4	546850, 5213850
	Annual	1.99	546812, 5212932	Annual	2.68	546850, 5213850
Acrolein	1-hr	3.21	546812, 5212932	1-hr	1.52	546850, 5213850
	8-hr	0.847	546812, 5212922	8-hr	0.454	546875, 5213850
	24-hr	0.413	546822, 5212932	24-hr	0.260	546850, 5213850
	Annual	0.0281	546812, 5212932	Annual	0.0379	546850, 5213850
Arsenic	1-hr	2.52E-04	546832, 5212932	1-hr	1.90E-04	547025, 5213850
	8-hr	7.69E-05	546812, 5212932	8-hr	6.91E-05	546875, 5213850
	24-hr	4.59E-05	546812, 5212932	24-hr	4.34E-05	546900, 5213850
	Annual	4.39E-06	546812, 5212932	Annual	7.22E-06	546850, 5213850
Cadmium	1-hr	1.39E-03	546832, 5212932	1-hr	1.05E-03	547025, 5213850
	8-hr	4.23E-04	546812, 5212932	8-hr	3.80E-04	546875, 5213850
	24-hr	2.53E-04	546812, 5212932	24-hr	2.39E-04	546900, 5213850
	Annual	2.41E-05	546812, 5212932	Annual	3.97E-05	546850, 5213850
Chromium (VI)	Annual	1.23E-06	546812, 5212932	Annual	2.02E-06	546850, 5213850
7,12-Dimethylbenz(a)anthracene	1-hr	2.02E-05	546832, 5212932	1-hr	1.52E-05	547025, 5213850
	8-hr	6.15E-06	546812, 5212932	8-hr	5.53E-06	546875, 5213850
	24-hr	3.67E-06	546812, 5212932	24-hr	3.47E-06	546900, 5213850
	Annual	3.51E-07	546812, 5212932	Annual	5.77E-07	546850, 5213850
Formaldehyde	1-hr	5.82	546812, 5212932	1-hr	2.80	546850, 5213850
	8-hr	1.54	546812, 5212922	8-hr	0.844	546875, 5213850
	24-hr	0.753	546822, 5212932	24-hr	0.486	546850, 5213850
	Annual	0.0525	546812, 5212932	Annual	0.0713	546850, 5213850
Nitrogen Dioxide	1-hr	14.1	546832, 5212932	1-hr	10.7	547025, 5213850
	Annual	0.246	546812, 5212932	Annual	0.405	546850, 5213850

6.2.1 Cumulative ECs

Cumulative exposures were evaluated by combining ECs based on facility-wide annual emissions and annual background air concentrations, estimated using the latest NATA data (described in Section 4.3). Cumulative ECs presented in Table 6-3 were used to estimate non-cancer hazards and cancer risk for all identified receptor groups in the Risk Characterization (see Section 8).

Table 6-3: Cumulative Exposure Concentrations

TAP	Averaging Period	MIBR ($\mu\text{g}/\text{m}^3$)	MIR ($\mu\text{g}/\text{m}^3$)	MIRR ($\mu\text{g}/\text{m}^3$)	MICR ($\mu\text{g}/\text{m}^3$)
Acetaldehyde	Annual	9.07	9.09	3.34	4.03
Acrolein	Annual	0.184	0.184	0.102	0.112
Arsenic	Annual	0.000167	0.000167	0.000156	0.000159
Cadmium	Annual	0.000129	0.000129	0.0000682	0.0000838
Chromium (VI)	Annual	0.000102	0.000102	0.0000992	0.000100
7,12-Dimethylbenz(a)anthracene	Annual	0.00000124	0.00000123	0.000000351	0.000000577
Formaldehyde	Annual	1.72	1.72	1.57	1.59
Nitrogen Dioxide	1-Hour	113	113	110	107
	Annual	12.6	12.6	11.9	12.1

7 Toxicity Assessment

Toxicity values from US EPA (IRIS and NAAQS), OEHHA, and ATSDR 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. EPA values are reference concentrations (RfC) for chronic exposure. OEHHA values are reference exposure levels (RELs), available for acute 1-hour, 8-hour, and chronic annual exposures. ATSDR toxicity values are called minimal risk levels (MRLs) and are available for acute (14 days or less), intermediate (15-364 days), and chronic (greater than one year) exposures. Table 7-2 provides the cancer inhalation unit risk factors. These values are available from EPA and OEHHA. When toxicity values (cancer or non-cancer) differ between two agencies, both values are carried through the Risk Characterization in Section 8.

The polycyclic aromatic hydrocarbon 7,12-dimethylbenz(a)anthracene does not have non-cancer toxicity values, therefore it cannot be quantified for non-cancer hazards. The EPA does not classify it as a carcinogen; however, OEHHA provides a cancer inhalation unit risk factor which was incorporated into the cancer risk estimates.

In Table 7-1, non-cancer values are presented for hexavalent chromium as particulates and as chromic acid mists. In the absence of information supporting the use of either form of chromium, emissions attributable to the facility are assumed to be chromic acid mists, which have lower, more health protective toxicity values. Toxicity values for chromium as particulates were not used to calculate hazards.

Table 7-1: Non-Cancer, Toxicity Values from EPA, OEHHA, and ATSDR

Chemical	Source	Type	Value (µg/m ³)
Acetaldehyde	EPA	Chronic RfC	9
	OEHHA	Acute REL	470
		8-Hour REL	300
		Chronic REL	140
Acrolein	EPA	Chronic RfC	0.02
	OEHHA	Acute REL	2.5
		8-Hour REL	0.7
		Chronic REL	0.35
	ATSDR	Acute MRL	7
		Intermediate MRL	0.09
Arsenic	OEHHA	Acute REL	0.2
		8-Hour REL	0.015
		Chronic REL	0.015
Cadmium	OEHHA	Chronic REL	0.02
	ATSDR	Acute MRL	0.03
		Chronic MRL	0.01
Chromium (VI), as particulates	EPA	Chronic RfC	0.1
	OEHHA	Chronic REL	0.2
	ATSDR	Intermediate MRL	0.3
Chromium (VI), as chromic acid mist	EPA	Chronic RfC	0.008
	ATSDR	Intermediate MRL	0.005
		Chronic MRL	0.005
Formaldehyde	OEHHA	Acute REL	55
		8-Hour REL	9
		Chronic REL	9
	ATSDR	Acute MRL	50
		Intermediate MRL	37
		Chronic MRL	10
Nitrogen Dioxide	EPA NAAQS	1-Hour NAAQS	188
		Annual NAAQS	100

Given the number of TAPs evaluated here, and in some cases multiple toxicity values per TAP, the basis for each value is not described here. Discussion is provided only for the toxicity values of the three TAPs that exceeded the ASIL. Additional details for the toxicity values not described here can be found on the referenced agency websites.

Table 7-2: Cancer Inhalation Unit Risk Values

Toxic Air Pollutant	Inhalation Unit Risk (per $\mu\text{g}/\text{m}^3$)	
	US EPA	OEHHA
Acetaldehyde	0.0000022	0.0000027
Acrolein	NA	NA
Arsenic	0.0043	0.0033
Cadmium	0.0018	0.0042
Chromium (VI)	0.012	0.15
7,12-Dimethylbenz(a)anthracene	--	0.071
Formaldehyde	0.000013	0.0000066
Nitrogen Dioxide	NA	NA

7.1 Acetaldehyde

As described in the hazard identification (Section 3), acetaldehyde inhalation may cause a variety of respiratory effects at certain concentrations. The EPA RfC, developed in 1991, is based on two short-term rat exposure studies. In the first, effects on the olfactory epithelium (such as decreases in cell density and viability and histopathological changes in the nasal cavity) were seen at 500 ppm²⁰. In this study, no effects were seen at 150 ppm over the 4-week exposure period. The no-observable-adverse-effect level (NOAEL) adjusted for human exposure is 8.7 mg/m³. In the second study, slight to severe degeneration of the nasal olfactory epithelium was seen at 400 ppm²¹, the concentration designated to be the lowest-observable-adverse-effect level (LOAEL), adjusted for human equivalency to a concentration of 16.9 mg/m³. Uncertainty factors were applied to the NOAEL: 10 for sensitive human populations, 10 for incomplete data and interspecies extrapolation, and 10 for subchronic to chronic exposure. This resulted in the RfC of 9 $\mu\text{g}/\text{m}^3$, which was given a designation of “low confidence” by EPA due to the use of limited, subchronic data.

OEHHA provides acute, 8-hour, and chronic RELs developed in 2008. The 8-hour REL and chronic REL are both based on the same two studies as the EPA RfC. OEHHA generated a benchmark concentration of 178 mg/m³ from the data. These results were then adjusted for the appropriate duration and uncertainty factors for an 8-hour REL of 300 $\mu\text{g}/\text{m}^3$ and a chronic REL of 140 $\mu\text{g}/\text{m}^3$.

The range of chronic toxicity values is 9 to 140 $\mu\text{g}/\text{m}^3$, with the EPA RfC at the low end of the range and the OEHHA REL at the high end. The EPA RfC is falls within the range for normal

²⁰ Appleman, L.M., R.A. Woutersen, V.J. Feron, R.N. Hooftman and W.R.F. Notten. 1986. Effect of variable versus fixed exposure levels on the toxicity of acetaldehyde in rats. *J. Appl. Toxicol.* 6(5): 331-336.

²¹ Appleman, L.M., R.A. Woutersen, and V.J. Feron. 1982. Inhalation toxicity of acetaldehyde in rats. I. Acute and subacute studies. *Toxicology.* 23: 293-297.

human breath, with acetaldehyde concentrations of 0.7 to 11 $\mu\text{g}/\text{m}^3$ ²². The OEHHA chronic REL is a more appropriate value for estimating hazards associated with inhalation of acetaldehyde as it represents an updated analysis, performed in 2008 using the same critical studies but the more advanced benchmark dose modeling methodology. Ultimately the use of a benchmark concentration, as well as a more realistic dosimetric adjustment factor (from a 2008 PBPK model²³), and smaller uncertainty factors result in a more technically sound estimate of acetaldehyde toxicity.

The acute acetaldehyde REL is based on a short-term study of human asthmatics exposed to aerosolized acetaldehyde solutions. The study determined the concentration at which the subjects experienced a 20 percent decrease in forced expiratory volume in one second²⁴. The 95 percent lower confidence interval of the mean concentration for this endpoint was chosen to be the LOAEL, at 142 mg/m^3 . Uncertainty factors totaling 300 were used (10 for use of a LOAEL instead of a NOAEL and 30 for extra sensitivity in children), resulting in the acute REL of 470 $\mu\text{g}/\text{m}^3$. This REL is also protective of eye irritation, which has a LOAEL of 45 $\mu\text{g}/\text{m}^3$ from a short-term study of 24 human volunteers²⁵.

Additionally, acetaldehyde is classified as a probable human carcinogen by the EPA, based on inhalation exposures resulting in nasal and laryngeal tumors in rat and hamster studies, respectively. The cancer inhalation unit risk factor is 2.2E-6 per $\mu\text{g}/\text{m}^3$. OEHHA developed an inhalation unit risk factor that is similar, 2.7E-6 per $\mu\text{g}/\text{m}^3$, based on rat nasal tumor incidence²⁶.

7.2 Acrolein

The EPA RfC (0.02 $\mu\text{g}/\text{m}^3$) is based on a 1978 subchronic rat study in which nasal lesions were reported at LOAEL of 0.4 ppm (0.9 mg/m^3)²⁷. The LOAEL adjusted for human exposure is 0.02 mg/m^3 , which incorporates uncertainty factors totaling 1,000 ($\sqrt{10}$ for interspecies extrapolation, 10 for sensitive subpopulations, 10 for subchronic to chronic duration, and $\sqrt{10}$ for use of a LOAEL instead of a NOAEL).

The chronic REL from OEHHA is an order of magnitude higher than the EPA RfC, at 0.35 $\mu\text{g}/\text{m}^3$. This value is based on a 2008 rat study showing lesions in the respiratory epithelium²⁸. The LOAEL was 0.6 ppm, and the NOAEL was 0.2 ppm. The NOAEL was adjusted

²² OEHHA. 2008. Appendix D. Individual Acute, 8-Hour, and Chronic Reference Exposure Level Summaries. TSD for Noncancer RELs, December 2008. Revised July 2014.

http://www.oehha.ca.gov/air/hot_spots/2008/AppendixD1_final.pdf#page=5

²³ Teeguarden JG, Bogdanffy MS, Covington TR, Tan C and Jarabek AM. 2008. A PBPK model for evaluating the impact of aldehyde dehydrogenase polymorphisms on comparative rat and human nasal tissue acetaldehyde dosimetry. *Inhal Toxicol* 20(4):375-90.

²⁴ Prieto L, Sanchez-Toril F, Brotons B, Soriano S, Casan R and Belenguer JL. 2000. Airway responsiveness to acetaldehyde in patients with asthma: Relationship to methacholine responsiveness and peak expiratory flow variation. *Clin Exp Allergy* 30(1): 71-78.

²⁵ Silverman L, Schultes HF and First MW. 1946. Further studies on sensory response to certain industrial solvent vapors. *J Ind Hyg Toxicol* 28: 262-266.

²⁶ Woutersen RA, Appleman LM, Van Garderen-Hoetmer A and Feron VJ. 1986. Inhalation toxicity of acetaldehyde in rats. III. Carcinogenicity study. *Toxicology* 41:213-232.

²⁷ Feron, VJ; Kryusse, A; Til, HP; et al. 1978. Repeated exposure to acrolein vapor: subacute studies in hamsters, rats and rabbits. *Toxicology* 9:47-57.

²⁸ Dorman DC, Struve MF, Wong BA, Marshall MW, Gross EA and Willson GA. 2008. Respiratory tract responses in male rats following subchronic acrolein inhalation. *Inhal Toxicol* 20(3): 205-16.

for chronic exposures and human equivalency. A cumulative uncertainty factor of 200 also was applied ($\sqrt{10}$ for subchronic to chronic duration, 2 for interspecies toxicokinetic uncertainty, $\sqrt{10}$ for lack of interspecies toxicodynamic data, and 10 to account of sensitive human populations).

The range in chronic toxicity values is 0.02 to 0.35 $\mu\text{g}/\text{m}^3$, with the EPA RfC at the low end and the OEHHA REL at the high end. These values differ for two main reasons: 1) The EPA used a regional gas dosimetric ratio of 0.14 to adjust the LOAEL whereas OEHHA used a dosimetric adjustment factor of 0.85, based on comparative models of mass flux through nasal passages of a rat and human²⁹; and 2) the OEHHA REL is also calculated with a cumulative uncertainty factor of 200, compared to 1,000 for the EPA RfC. The lower cumulative uncertainty factor was possible because the critical study reported a NOAEL and interspecies variability was accounted for by the dosimetric adjustment factor (though an uncertainty factor of 2 was still included because the dosimetric adjustment factor was based on formaldehyde, a chemical analogue). Given the higher uncertainty associated with the RfC, we put greater confidence in the OEHHA REL for the calculation of non-cancer hazards.

The OEHHA 8-hour REL is based on the same study as the chronic REL, adjusting for 8-hour worker exposures rather than chronic exposures. This resulted in an 8-hour REL of 0.70 $\mu\text{g}/\text{m}^3$.

The acute OEHHA REL is the geometric mean of the REL values from two different studies, Darley et al. and Weber-Tschopp et al. Both studies were performed on healthy human volunteers exposed to acrolein in a chamber for short durations. The critical endpoint selected from Darley *et al.* was irritation of the eyes, with a LOAEL of 0.06 ppm³⁰. An uncertainty factor of 60 was applied (6 for use of a LOAEL instead of a NOAEL, 10 for sensitive populations), to result in an REL of 1 ppb (2.3 $\mu\text{g}/\text{m}^3$). From the Weber-Tschopp *et al.* study, the chosen critical effect was also of ocular irritation, with a LOAEL of 0.07 ppm³¹. The same uncertainty factors were applied, resulting in an REL of 1.2 ppb (2.7 $\mu\text{g}/\text{m}^3$). The geometric mean of the REL values from these two studies is 2.5 $\mu\text{g}/\text{m}^3$.

ATSDR provides an acute MRL of 0.003 ppm (7 $\mu\text{g}/\text{m}^3$) based on a LOAEL of 0.3 ppm in humans from the same Weber-Tschopp *et al.* study that was used by OEHHA. The critical effects included irritation of the nose and throat and decreased respiratory rate. Uncertainty factors of 100 were applied (10 for sensitive subpopulations and 10 for use of a LOAEL instead of a NOAEL). This MRL is higher than the OEHHA acute value.

ATSDR also provides an intermediate MRL of 0.09 $\mu\text{g}/\text{m}^3$. This value was based on a LOAEL of 0.4 ppm for nasal metaplasia in the 1978 Feron *et al.* rat study used to derive the EPA RfC. The intermediate duration of 15 to 364 days is not a standard exposure time for modeling air concentrations. Also, acute (1-hour and 8-hour) and chronic hazard indices are expected to be

²⁹ OEHHA. 2008. Appendix D. Individual Acute, 8-Hour, and Chronic Reference Exposure Level Summaries. TSD for Noncancer RELs, December 2008. Revised July 2014
http://www.oehha.ca.gov/air/hot_spots/2008/AppendixD1_final.pdf#page=47

³⁰ Darley E, Middleton J and Garber M. 1960. Plant damage and eye irritation from ozone-hydrocarbon reactions. *Agricul Food Chem* 8(6):483-484

³¹ Weber-Tschopp A, Fischer T, Gierer R and Grandjean E. 1977. [Experimentally induced irritating effects of acrolein on men (author's transl)]. *Int Arch Occup Environ Health* 40(2): 117-30.

health protective of intermediate duration exposures. As a result, this toxicity value was not used quantitatively in the Risk Characterization.

Acrolein has not been classified as a carcinogen.

7.3 Formaldehyde

Formaldehyde is also a respiratory irritant, as described in Section 3. The EPA does not provide an RfC for formaldehyde exposure. However, OEHHA provides an acute, 8-hour, and an annual REL, and ATSDR provides an acute, intermediate, and annual MRL.

The chronic and 8-hour RELs are the same, at $9 \mu\text{g}/\text{m}^3$, and based on the same study showing nasal and eye irritation from occupational exposure over an average of 10 years³². The LOAEL from the study was a mean of $0.26 \text{ mg}/\text{m}^3$ from the exposed group. A NOAEL of $0.09 \text{ mg}/\text{m}^3$ was also provided from a control group. This NOAEL was used to determine both the chronic and 8-hour RELs, after applying an uncertainty factor of 10 to account for sensitive populations (asthma in children).

The ATSDR chronic MRL is $10 \mu\text{g}/\text{m}^3$ (8 ppb). It is based on a study of occupational exposures resulting in histological changes in nasal tissue over an average of 10 years of exposure³³. This toxicity value is very similar to the chronic REL.

An acute REL of $55 \mu\text{g}/\text{m}^3$ was derived from a human study of 19 healthy subjects given short term exposures to formaldehyde with an endpoint of eye irritation³⁴. OEHHA chose a NOAEL of 0.5 ppm and a LOAEL of 1 ppm, from which a benchmark concentration of 0.44 ppm was derived. An uncertainty factor of 10 was added to account for asthma exacerbation in children. The ATSDR acute MRL is a similar value, at $50 \mu\text{g}/\text{m}^3$ (40 ppb). This value is based on a LOAEL of 400 ppb from a study of human volunteers reporting itching, sneezing, mucosal congestion, and a burning sensation in the eyes and nasal passages after a 2 hour exposure³⁵. An uncertainty factor of 9 was applied for use of a LOAEL instead of a NOAEL and to account for sensitive populations.

The intermediate MRL was derived by ATSDR based on lesions in the nasal epithelium and other signs of nasopharyngeal irritation in Cynomolgus monkeys exposed to formaldehyde for 26 weeks for 5 days/week, 22 hours/day³⁶. A LOAEL of 2.95 ppm was provided. ATSDR applied an uncertainty factor of 10 for human variability and 3 for interspecies extrapolation to result in an MRL of 0.03 ppm ($37 \mu\text{g}/\text{m}^3$). As discussed for the acrolein intermediate MRL, this exposure

³² Wilhelmsson B, and Holmstrom M. 1992. Possible mechanisms of formaldehyde-induced discomfort in the upper airway. *Scand. J. Work. Environ. Health* 18(6):403-407.

³³ Holmstrom M, Wilhelmsson B, Hellquist H, et al. 1989. Histological changes in the nasal mucosa in persons occupationally exposed to formaldehyde alone and in combination with wood dust. *Acta Otolaryngol (Stockh)* 107:120-129.

³⁴ Kulle TJ, Sauder LR, Hebel JR, Green DJ and Chatham MD. 1987. Formaldehyde dose-response in healthy nonsmokers. *Japca* 37(8): 919-24.

³⁵ Pazdrak K, Gorski P, Krakowiak A, et al. 1993. Changes in nasal lavage fluid due to formaldehyde inhalation. *Int Arch Occup Environ Health* 64:515-519.

³⁶ Rusch GM, Clary JJ, Rinehart WE, et al. 1983. A 26-week inhalation toxicity study with formaldehyde in the monkey, rat, and hamster. *Toxicol Appl Pharmacol* 68:329-343

time is not standard for air modeling; this toxicity value was not used quantitatively in the Risk Characterization.

The EPA's cancer weight-of-evidence characterization for formaldehyde states that there is limited human evidence and sufficient animal evidence to classify the chemical as a probable human carcinogen. Limited human studies of carcinogenicity focused on cancers of the lung and nasopharynx from persons exposed occupationally. EPA's inhalation unit risk factor is $1.3E-5$ per $\mu\text{g}/\text{m}^3$. The OEHHA inhalation unit risk factor is $6E-6$ per $\mu\text{g}/\text{m}^3$, based on nasal squamous carcinoma data in rats and supported by a human occupational exposure study^{37,38}.

³⁷ Kerns WD, Pavkov KL, Donofrio DJ, Gralla EJ and Swenberg JA. 1983. Carcinogenicity of formaldehyde in rats and mice after long-term inhalation exposure. *Cancer Res* 43:4382-4392.

³⁸ U.S. Environmental Protection Agency (US EPA) 1987. Assessment of Health Risks to Garment Workers and Certain Home Residents from Exposure to Formaldehyde. Office of Pesticide and Toxic Substances.

8 Risk Characterization

For the risk characterization, the results of the exposure and toxicity assessments are integrated into quantitative or qualitative estimates of potential health hazards. Cancer risk and non-cancer hazard estimates were quantified for the MIRR, MICR, MIR and MIBR. Because the MIR and MIBR were in virtually the same location, resulting in the same risks, the results from these two receptors are presented together. Where available, background concentrations were added to concentrations attributable to the facility for calculation of cumulative non-cancer hazard quotients and cancer risks.

8.1 Calculation of Non-Cancer Hazards

The potential for non-cancer adverse health effects from exposure to acetaldehyde, acrolein, and formaldehyde were evaluated by comparing exposure concentrations at the identified receptors to relevant non-cancer toxicity value 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 for an adverse health effect is quantified by the hazard quotient (HQ), which is calculated by dividing the EC by the relevant toxicity value. An HQ of one (1) 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 used to derive toxicity values, a value greater than one does not necessarily mean a negative health impact will occur.

Because arsenic, cadmium, chromium (VI), and nitrogen dioxide have similar target organs as the three TAPs that exceed the ASIL, the non-cancer hazards associated with the exposure concentrations from these compounds were also calculated and summed. The hazard quotients from the same averaging periods and receptors were summed across these chemicals to generate a hazard index that accounts for overall risk of non-cancer health effects.

Non-cancer hazards are presented with ranges where the toxicity values from different agencies are carried through the analysis, as described in Section 7.

Maximally Impacted Receptor (MIR)/Maximally Impacted Boundary Receptor (MIBR)

Due to the variability in toxicity values provided by multiple agencies, the highest and lowest non-cancer hazards for the MIR/MIBR vary significantly, as shown in Table 8-1 and Table 8-2. The hazard index for 1-hour exposures exceeds one and is driven by the concentrations of acetaldehyde and acrolein. The 8-hour hazard index exceeds 1 due to acrolein concentrations. The annual hazard index ranges from less than one (no adverse health effects would be expected to occur) up to 6. When annual background concentrations are added to the facility emissions, the annual hazard index ranges from 0.8 to 10.

The annual hazard indices that exceed one are driven by the EPA RfC for acrolein. The only individual TAP with an HQ greater than one is acrolein, which exceeds one only when based on the EPA RfC. The background acrolein concentrations alone exceed the RfC. As described in Section 7.2, EPA places low confidence in the acrolein RfC and there is less uncertainty associated with the HQ based on the REL.

The MIR/MIBR is a worst-case scenario. The annual hazard index assumes that a person lives on the boundary of the facility, chronically exposed to emissions from the facility for a lifetime.

Table 8-1: Non-Cancer Hazard Quotients for MIR/MIBR, 1-hour and 8-hour

TAP	1-hour			8-hour
	EPA	OEHHA	ATSDR	OEHHA
Acetaldehyde		0.6		0.3
Acrolein		2	0.6	2
Arsenic		0.002		0.01
Cadmium			0.06	
Chromium (VI)				
Formaldehyde		0.1	0.1	0.3
Nitrogen Dioxide	0.09			
Hazard Index	1 – 3			3

Table 8-2: Non-Cancer Hazard Quotients for MIR/MIBR, Annual

TAP	Facility Only			Cumulative (Facility + Background)		
	EPA	OEHHA	ATSDR	EPA	OEHHA	ATSDR
Acetaldehyde	0.9	0.06		1	0.06	
Acrolein	5	0.3		9	0.5	
Arsenic		0.001			0.01	
Cadmium		0.004	0.008		0.006	0.01
Chromium (VI)	0.001		0.001	0.01		0.02
Formaldehyde		0.02	0.02		0.2	0.2
Nitrogen Dioxide*	0.01			0.01		
Hazard Index	0.4 – 6			0.8 – 10		

*Background concentration not available

Maximally Impacted Residential Receptor (MIRR)

For the MIRR, the non-cancer hazards are lower than for the MIR/MIBR, though they still vary significantly due to the range in toxicity values for acetaldehyde and acrolein. As shown in Table 8-3, the acute 1-hour hazard index ranges from 1 to 2, and the 8-hour hazard index is 2. The annual facility-only scenario hazard index ranges from 0.1 to 2 (Table 8-4). The cumulative annual scenario hazard index ranges from 0.5 to 6. As with the MIR/MIBR, for all averaging

periods, acrolein is the only individual TAP that exceeds an HQ of one. For the annual averaging period, use of the EPA RfC for acrolein results in an HQ greater than one, while the OEHHA REL does not.

Table 8-3: Non-Cancer Hazard Quotients for MIRR, 1-hour and 8-hour

TAP	1-hour			8-hour
	EPA	OEHHA	ATSDR	OEHHA
Acetaldehyde		0.5		0.2
Acrolein		1	0.5	1
Arsenic		0.001		0.01
Cadmium			0.05	
Chromium (VI)				
Formaldehyde		0.1	0.1	0.2
Nitrogen Dioxide	0.08			
Hazard Index	1 – 2			2

Table 8-4: Non-Cancer Hazard Quotients for MIRR, Annual

TAP	Facility Only			Cumulative (Facility + Background)		
	EPA	OEHHA	ATSDR	EPA	OEHHA	ATSDR
Acetaldehyde	0.2	0.01		0.4	0.02	
Acrolein	1	0.08		5	0.3	
Arsenic		0.0003			0.01	
Cadmium		0.001	0.002		0.003	0.007
Chromium (VI)	0.0002		0.0002	0.01		0.02
Formaldehyde		0.006	0.005		0.2	0.2
Nitrogen Dioxide*	0.002			0.002		
Hazard Index	0.1 – 2			0.5 – 6		

*Background concentration not available

Maximally Impacted Commercial Receptor (MICR)

The MICR is located where a commercial facility currently operates. The hazard index shows that for 1-hour and 8-hour exposures, no adverse health effects are expected to occur (Table 8-5). The annual hazard index for the facility only ranges from 0.1 to 2 (Table 8-6). The annual hazard index for the cumulative scenario ranges from 0.5 to 6.

For annual exposures, which assume constant exposure, the hazard index ranges from 0.1 to 2, driven by the hazard quotient based on the EPA RfC for acrolein. When background emissions are included in the cumulative scenario, the hazard index ranges from 0.5 to 6, also driven by the EPA RfC for acrolein.

Table 8-5: Non-Cancer Hazard Quotients for MICR, 1-hour and 8-hour

TAP	1-hour			8-hour
	EPA	OEHHA	ATSDR	OEHHA
Acetaldehyde		0.2		0.1
Acrolein		0.6	0.2	0.6
Arsenic		0.001		0.005
Cadmium			0.03	
Chromium (VI)				
Formaldehyde		0.05	0.06	0.09
Nitrogen Dioxide	0.06			
Hazard Index	0.6 – 1			0.9

Table 8-6: Non-Cancer Hazard Quotients for MICR, Annual

TAP	Facility Only			Cumulative (Facility + Background)		
	EPA	OEHHA	ATSDR	EPA	OEHHA	ATSDR
Acetaldehyde	0.3	0.02		0.4	0.03	
Acrolein	2	0.1		6	0.3	
Arsenic		0.0005			0.01	
Cadmium		0.002	0.004		0.004	0.008
Chromium (VI)	0.0003		0.0004	0.01		0.02
Formaldehyde		0.008	0.007		0.2	0.2
Nitrogen Dioxide*	0.004			0.004		
Hazard Index	0.1 – 2			0.5 – 6		

*Background concentration not available

8.2 Quantifying Increased Cancer Risks

Cancer risks represent the hypothetical increase in cancers per number of people exposed. For example, a cancer risk of 1E-06 means that one additional cancer may occur for one million people exposed. These values are calculated by multiplying the annual EC by the inhalation unit

risk factor (presented in Section 7). According to Ecology, the acceptable increased cancer risk is no more than 10 per million or 1E-05.

Acrolein and nitrogen dioxide are not carcinogens and are therefore not included in the cancer risk calculations. For the remaining six TAPs, EPA and OEHHA provide differing inhalation unit risk factors. The risk calculations are performed using both the EPA and OEHHA values. A sum of the cancer risks for each TAP is also calculated as the overall cancer risk from emissions attributed to the facility. Finally, cumulative cancer risks are calculated by combining the emissions attributable to the facility with background concentrations and summing across all chemicals.

Maximally Impacted Receptor (MIR)/Maximally Impacted Boundary Receptor (MIBR)

Increased cancer risks for the MIR/MIBR are 20 per million from facility emissions and 40 to 50 per million from cumulative emissions. The cancer risks are driven by acetaldehyde in the Facility only scenario, and both acetaldehyde and formaldehyde in the cumulative scenario. The MIR/MIBR is a worst case scenario that assumes a person lives on the facility boundary for a lifetime. Additionally, cancer risks from background formaldehyde alone range from 10 to 20 per million. Therefore, any emissions of formaldehyde from the facility would cause the cumulative cancer risk to exceed 10 per million.

Table 8-4: Cancer Risks for MIR/MIBR

TAP	Facility Only		Cumulative (Facility + Background)	
	EPA	OEHHA	EPA	OEHHA
Acetaldehyde	2E-05	2E-05	2E-05	2E-05
Arsenic	7E-08	5E-08	7E-07	6E-07
Cadmium	2E-07	4E-07	2E-07	5E-07
Chromium, hexavalent	5E-08	6E-07	1E-06	2E-05
7,12-Dimethylbenz(a)anthracene*	--	9E-08	--	9E-08
Formaldehyde	3E-06	1E-06	2E-05	1E-05
Sum of Cancer Risk	2E-05	2E-05	4E-05	5E-05

*Background concentration not available

Maximally Impacted Residential Receptor (MIRR)

Cancer risks for the MIRR range from 5 to 6 per million (below the limit of 10 per million). Cumulative cancer risks for the MIRR range from 30 to 40 per million. In the cumulative scenario the risks are driven by background air concentrations of formaldehyde, as explained for the MIR/MIBR.

Table 8-5: Cancer Risks for MIRR

TAP	Facility Only		Cumulative (Facility + Background)	
	EPA	OEHHA	EPA	OEHHA
Acetaldehyde	4E-06	5E-06	7E-06	9E-06
Arsenic	2E-08	1E-08	7E-07	5E-07
Cadmium	4E-08	1E-07	1E-07	3E-07
Chromium, hexavalent	1E-08	2E-07	1E-06	1E-05
7,12-Dimethylbenz(a)anthracene*	--	2E-08	--	2E-08
Formaldehyde	7E-07	3E-07	2E-05	1E-05
Sum of Cancer Risk	5E-06	6E-06	3E-05	4E-05

*Background concentration not available

Maximally Impacted Commercial Receptor (MICR)

Increased cancer risks at the MICR range from 7 to 8 per million from emissions from the facility, which is below the limit of 10 per million. Cumulative emissions range from 30 to 40 per million, with risks driven by formaldehyde (as explained for the MIR/MIBR).

Table 8-6: Cancer Risks for MICR

TAP	Facility Only		Cumulative (Facility + Background)	
	EPA	OEHHA	EPA	OEHHA
Acetaldehyde	6E-06	7E-06	9E-06	1E-05
Arsenic	3E-08	2E-08	7E-07	5E-07
Cadmium	7E-08	2E-07	2E-07	4E-07
Chromium, hexavalent	2E-08	3E-07	1E-06	2E-05
7,12-Dimethylbenz(a)anthracene*	--	4E-08	--	4E-08
Formaldehyde	9E-07	5E-07	2E-05	1E-05
Sum of Cancer Risk	7E-06	8E-06	3E-05	4E-05

*Background concentration not available

9 Discussion and Conclusions

9.1 Uncertainty Characterization

The HIA involves several assumptions, each with an associated uncertainty. In particular, there are uncertainties associated with the emissions rate calculations, air dispersion modeling, background concentrations, and toxicity values.

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 board foot of lumber dried), and an activity rate, which is a measure of an activity per unit time (e.g., board feet of lumber dried).

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. In this case, rather than assume an annual throughput for each species of lumber the facility is permitted to process and calculate a composite emission factor for each TAP, the worst-case emission factor for each TAP from among the species to be processed was applied to the entire annual throughput for each TAP.

Regarding activity rates, the kilns were assumed to dry the permitted quantity of lumber every year, and the boiler was assumed to operate continuously throughout the year (i.e., 8,760 hours per year) at 100 percent load. The current draft of the Order of Approval issued by PSCAA contains reporting and recordkeeping mechanisms to ensure that SPI does not exceed the permitted throughput limits, meaning that the activity rates used to calculate emissions represent real upper bounds that are unlikely to be exceeded. Boiler activity was based on physical limitations (i.e., maximum load and hours per year), which are even less likely to be 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 ASOS station located at McChord Field. The ASOS program is a joint effort of the NWS, the Federal Aviation Administration (FAA), and the Department of Defense (DOD), and is the primary surface weather observing network in the U.S. ASOS is designed primarily to support weather forecast activities and aviation operations, so it utilizes the most modern sensors, has excellent data recovery, and employs rigorous quality assurance procedures. With respect to representativeness, the terrain between McChord Field and the site proposed for the facility is not complex (i.e., it is relatively flat), and the proposed site is located approximately 7 miles from the airport. 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 proposed facility site, background concentrations for most compounds of interest were estimated using an annual average concentration from the 2005 NATA. The NATA provides only annual average concentrations, so short-term background concentrations were not estimated.

Acetaldehyde, acrolein, and formaldehyde degrade in the atmosphere, a fact that was not considered in the model. These three TAPs have degradation half-lives of less than 20 hours; therefore the annual exposure concentrations are overestimated. However, some of the degradation by-products may also have toxicity that can increase risk to the population. Because there are several by-products and environmental and seasonal conditions affect the degradation pathway, it was beyond the scope of this assessment to quantify the risks from these by-products.

9.1.4 Toxicity Values

There is uncertainty associated with development of toxicity values. 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 a particular exposure duration (acute or chronic). This requires the use of uncertainty factors. The magnitude of the uncertainty factors is often based on professional judgment, and may differ between agencies.

Due to differences in critical study selection, method for calculating the LOAEL/NOAEL, and application of uncertainty factors, EPA toxicity values for acetaldehyde, acrolein, and chromium (VI) are two to three orders of magnitude lower than the corresponding chronic toxicity values from OEHHA and ATSDR. These differences resulted in hazard indices that ranged from below 1, not expected to result in adverse health effects, to greater than 1. Given the significance of the range spanning the threshold of one, careful consideration of the underlying toxicity value is warranted. In the case of acrolein, the low confidence placed by EPA in the RfC and OEHHA's application of the preferred benchmark dose method for the REL derivation, among other factors, provide greater support for the HQ based on the REL.

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

Based on the risk characterization, acute (1-hour and 8-hour) health effects may occur for receptors located at or near the facility boundary, where hazard quotients were slightly greater than one due to acrolein. Acute health effects may include irritation to the eyes or upper respiratory tract. Though possible, it is unlikely for a worker or other receptor to be outdoors at the facility boundary for 8-hours, so these risks may be unrealistically high. At the nearest existing commercial receptor, acute health effects are not expected to occur, as hazard indices did not exceed one.

For all receptors, the annual hazard indices do not exceed one if the OEHHA REL for acrolein is used instead of the EPA RfC. For the cumulative scenario which considers background concentrations from acetaldehyde, acrolein, and formaldehyde, the hazard quotients do not exceed one when the OEHHA REL for acrolein is applied.

9.2.2 Cancer Risks

The sum of the increased cancer risks from TAP emissions attributable to the facility does not exceed 10 per million for the MIRR or MICR. For the MIR and MIBR, cancer risks from TAP emissions attributable to the facility are 20 per million; however, these are worst-case scenarios. Exposures at the facility boundary represented by the MIR and MIBR are not expected to occur for a lifetime.

When background emissions of acetaldehyde and formaldehyde are considered, the background concentration of formaldehyde alone is between 10 and 20 per million. Adding this background concentration to Facility emissions estimates results in cumulative cancer risks exceeding 10 per million for all receptor locations, regardless of facility emissions.

Figures

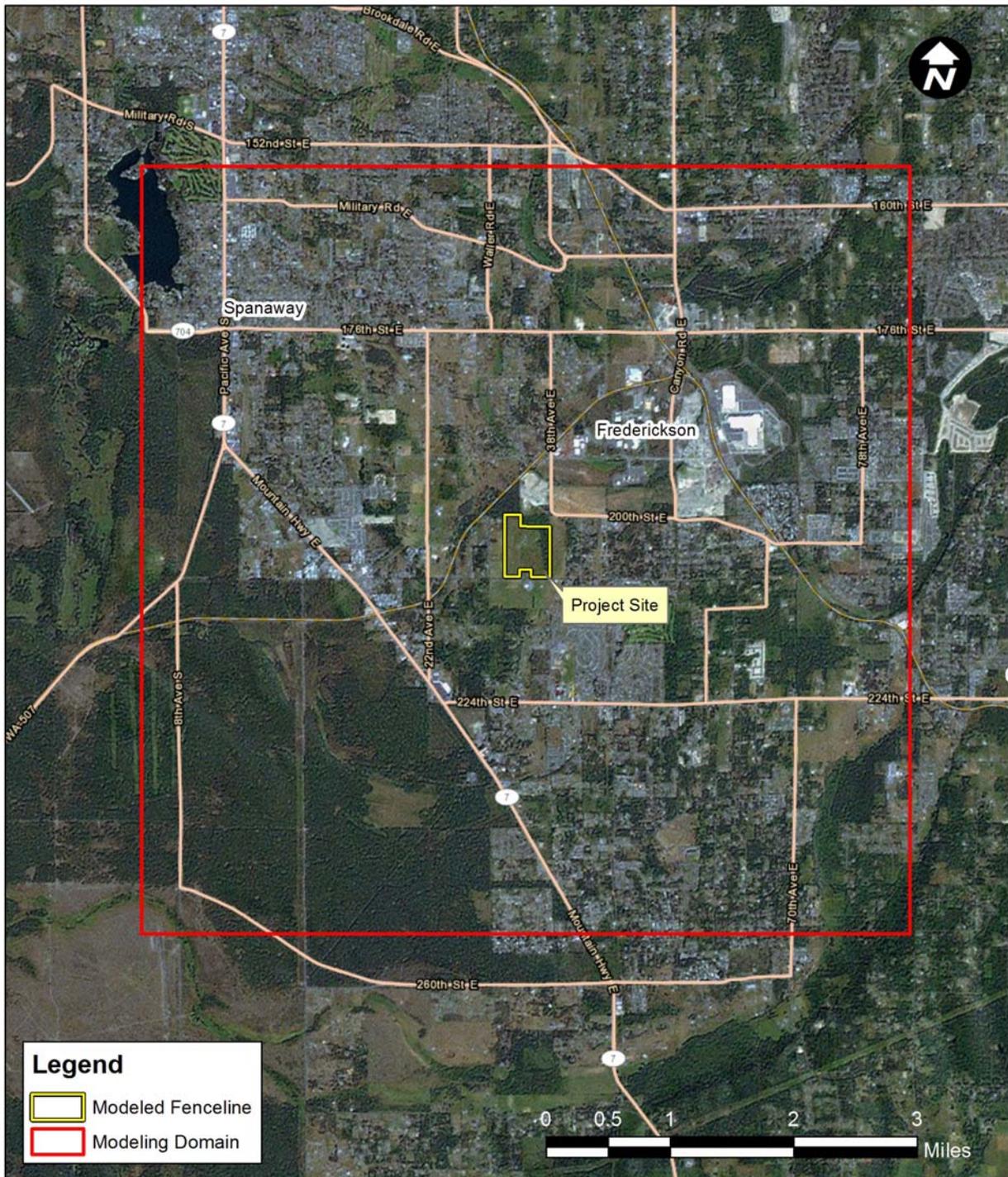


Figure 2-1: Locations of Facility and Modeling Domain

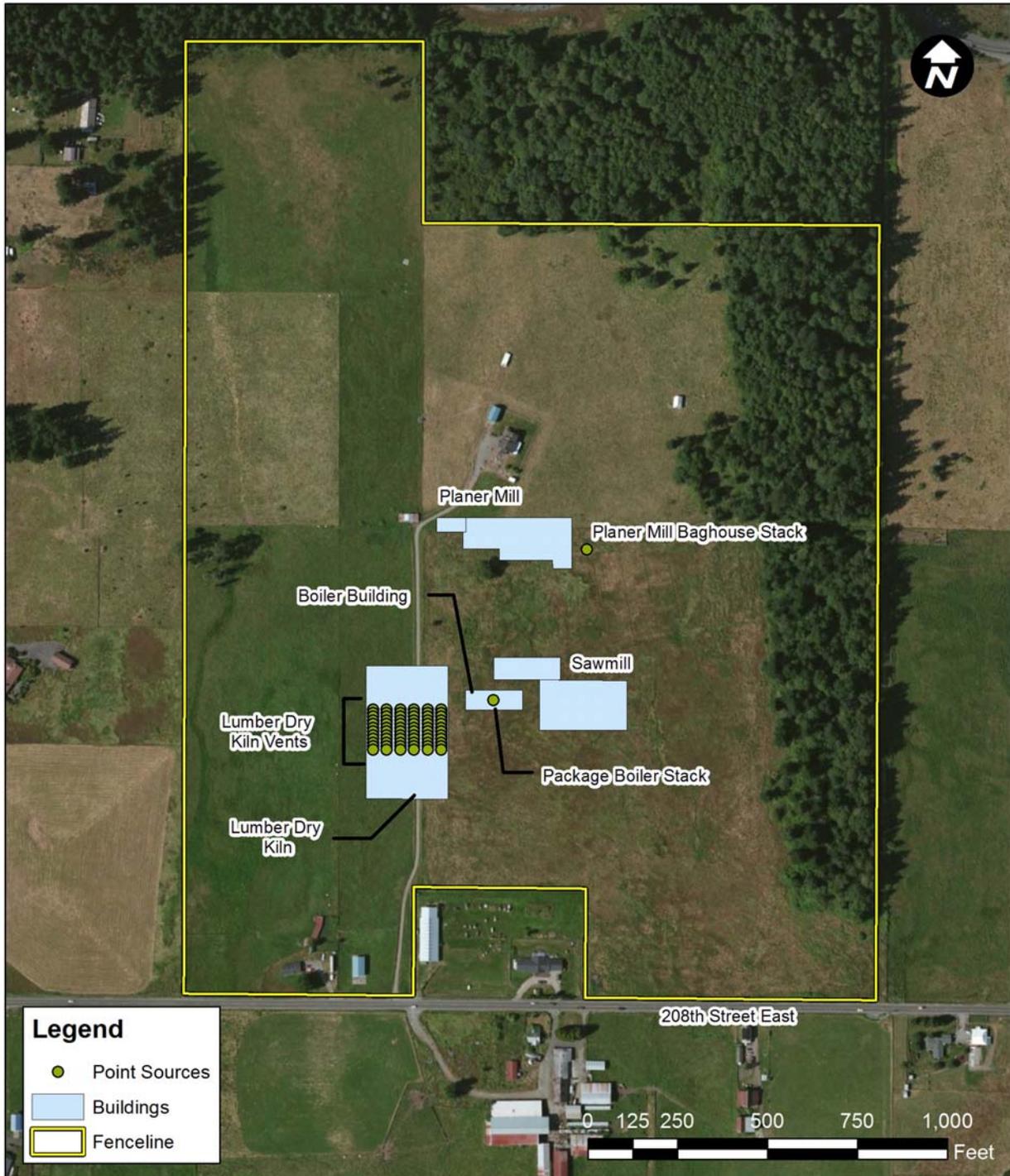


Figure 2-2: Facility Layout

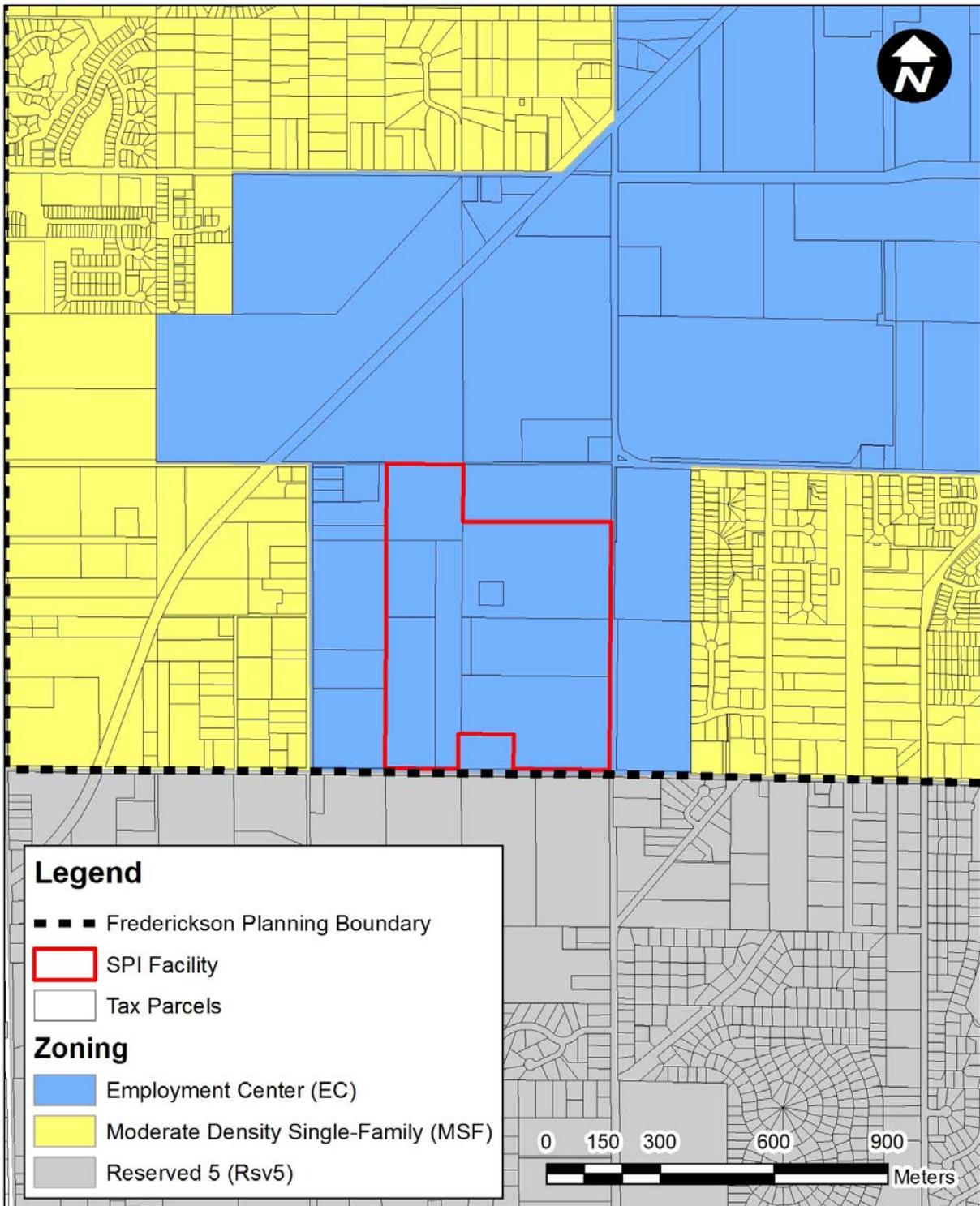


Figure 2-3: Zoning of Area Surrounding Facility

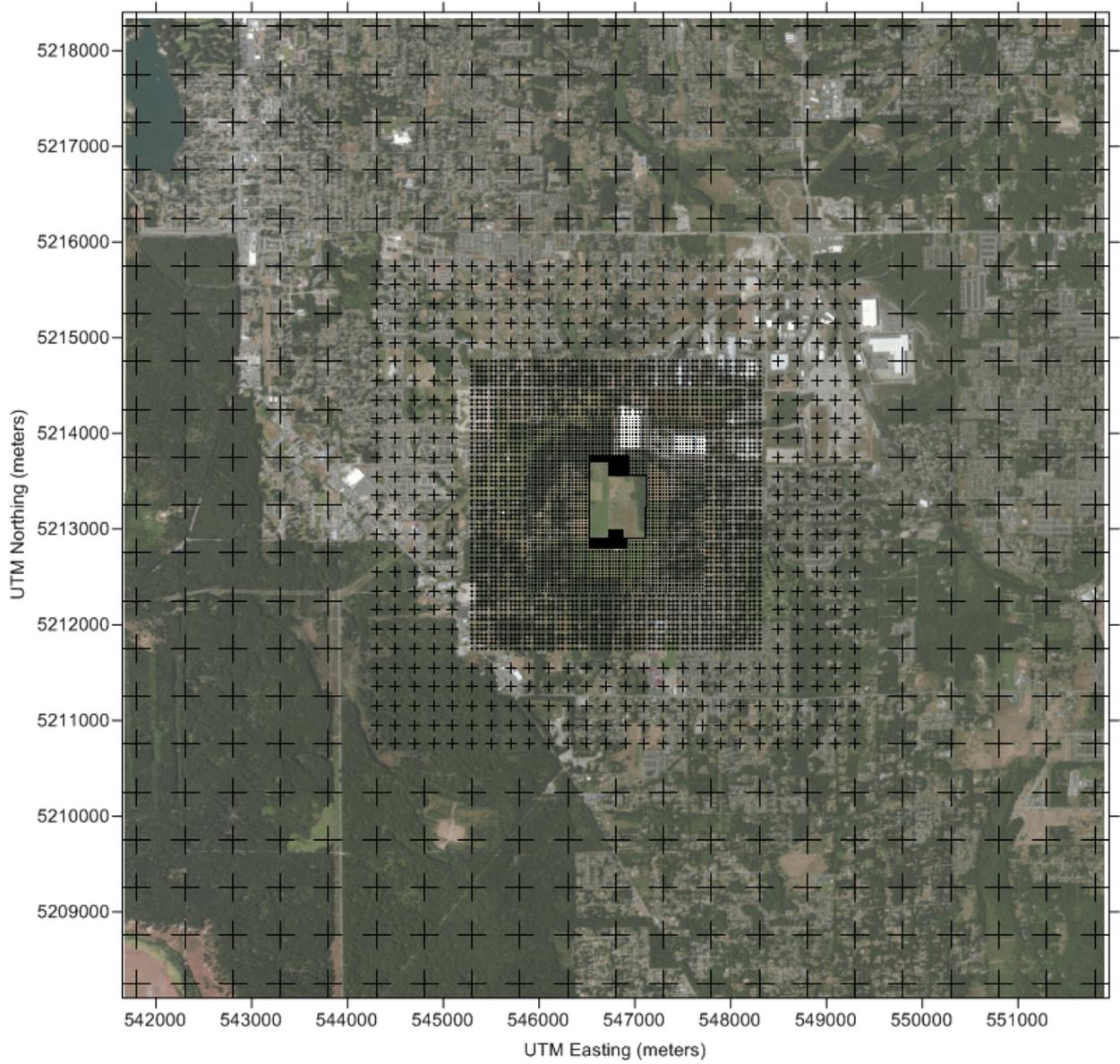


Figure 4-1: Final Receptor Locations

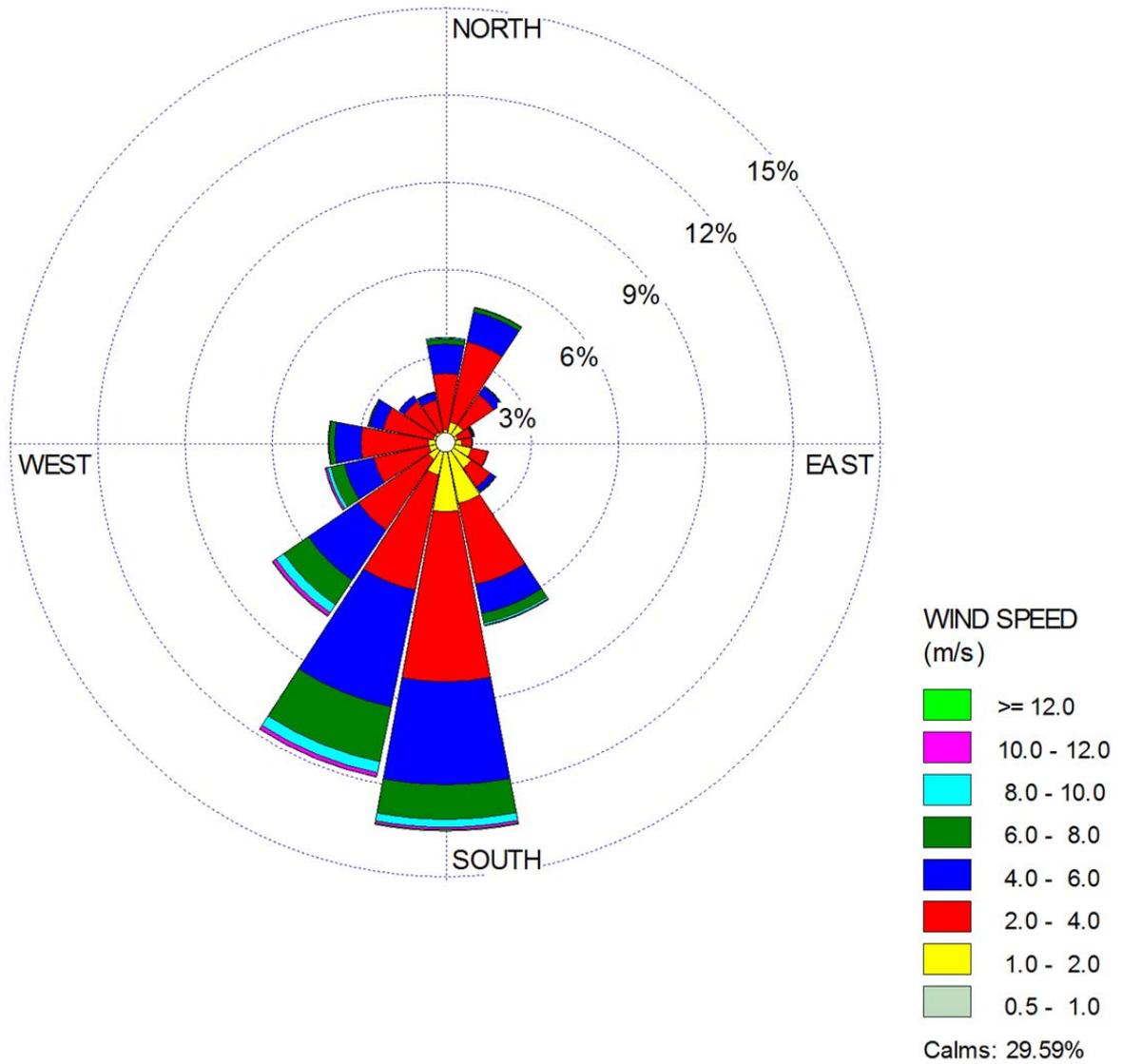


Figure 4-2: Wind Speed and Wind Direction at McChord Field, 2008 – 2012

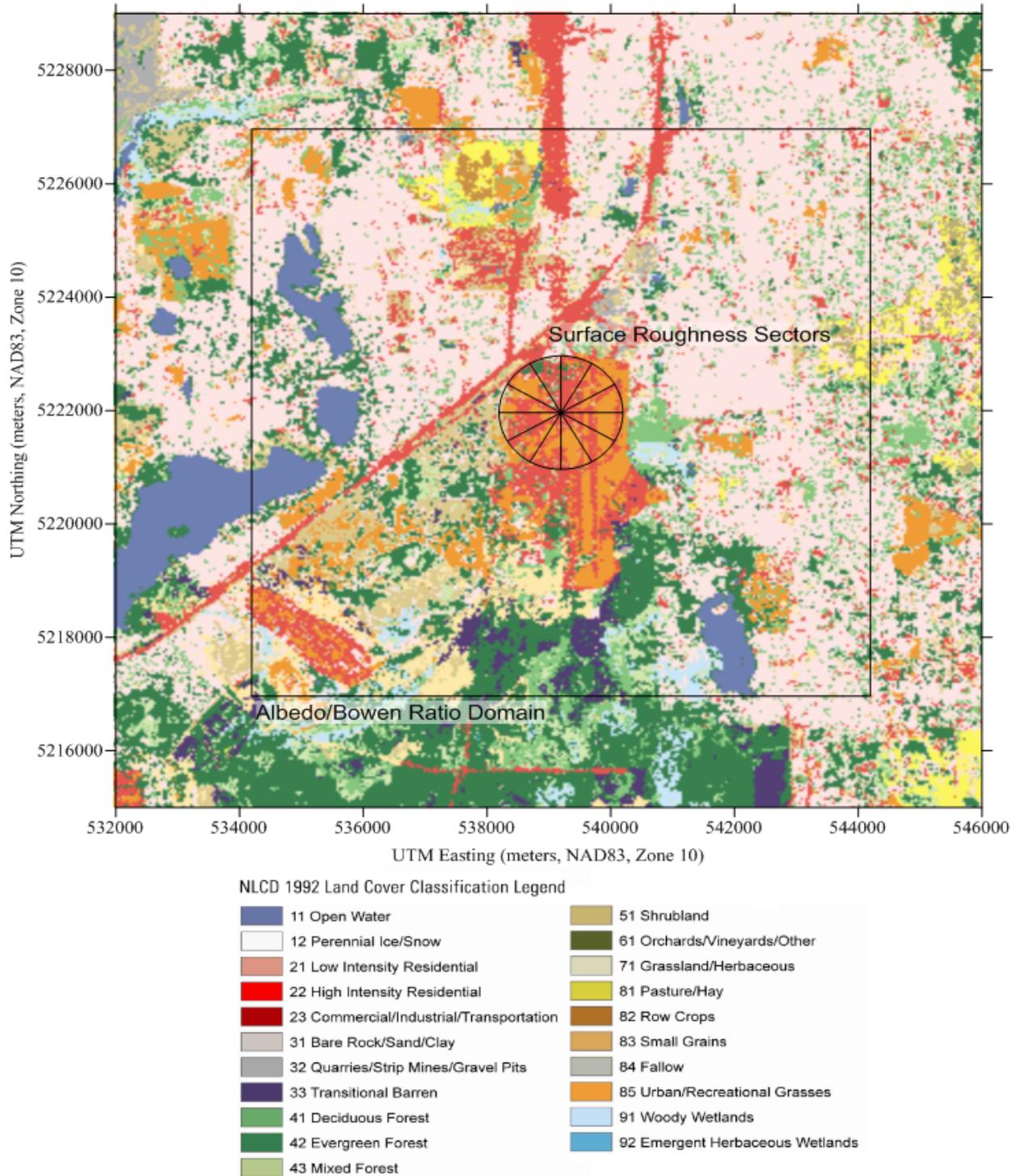


Figure 4-3: Land-Use Processing Domains

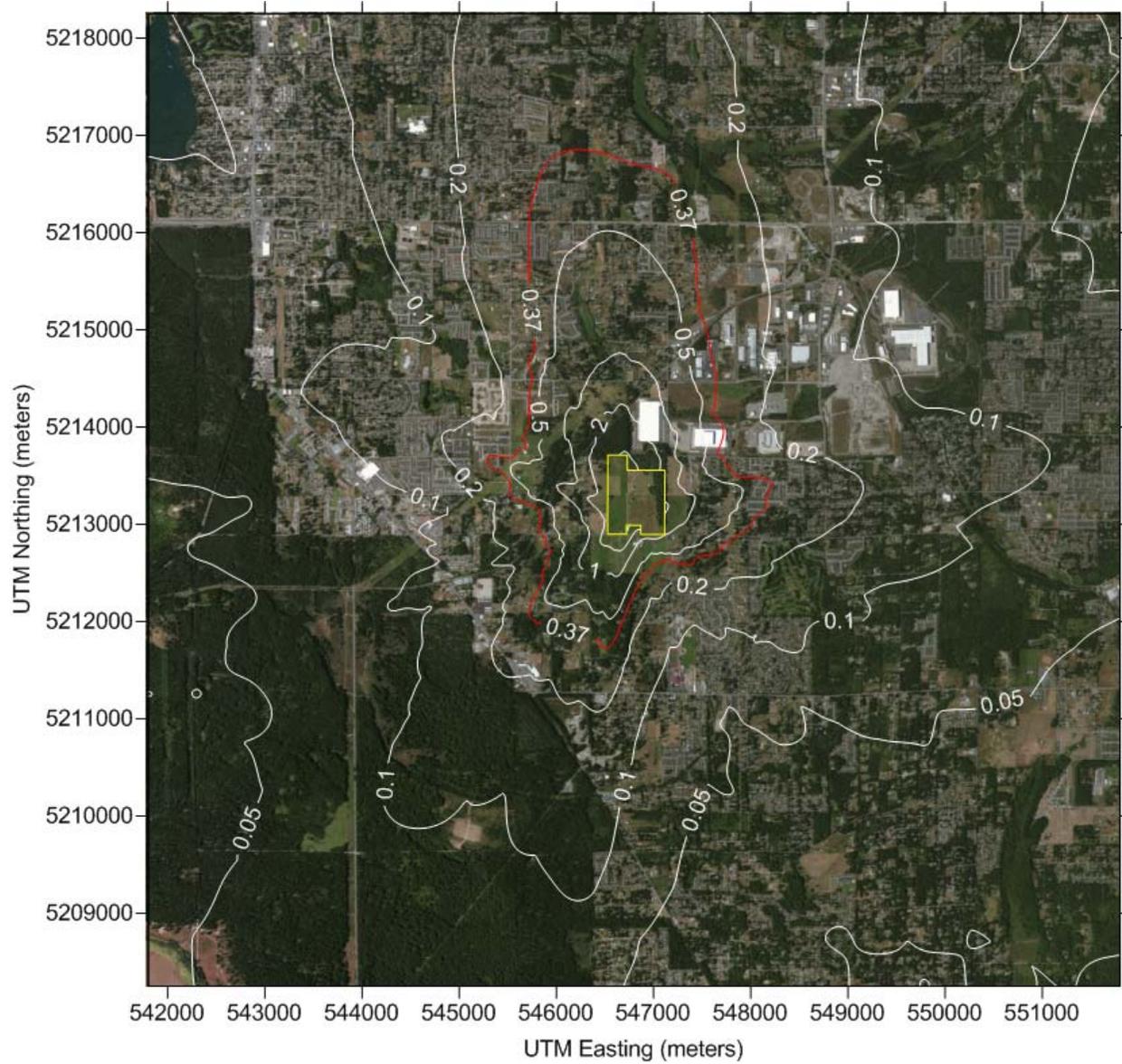


Figure 4-4: Max. Predicted Annual Average Acetaldehyde Conc. ($\mu\text{g}/\text{m}^3$) – Domain

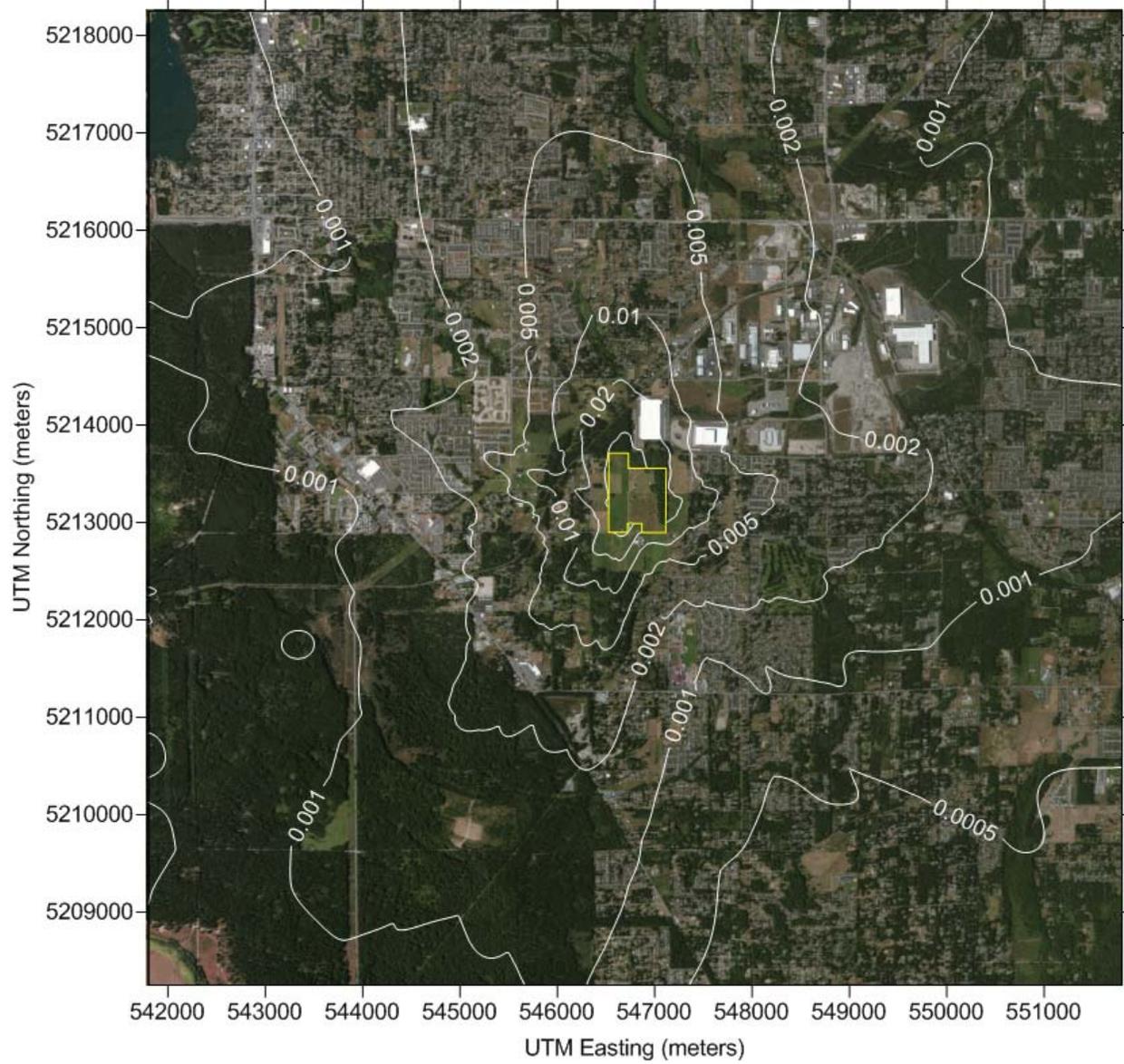


Figure 4-5: Max. Predicted Annual Average Acrolein Conc. ($\mu\text{g}/\text{m}^3$) – Domain

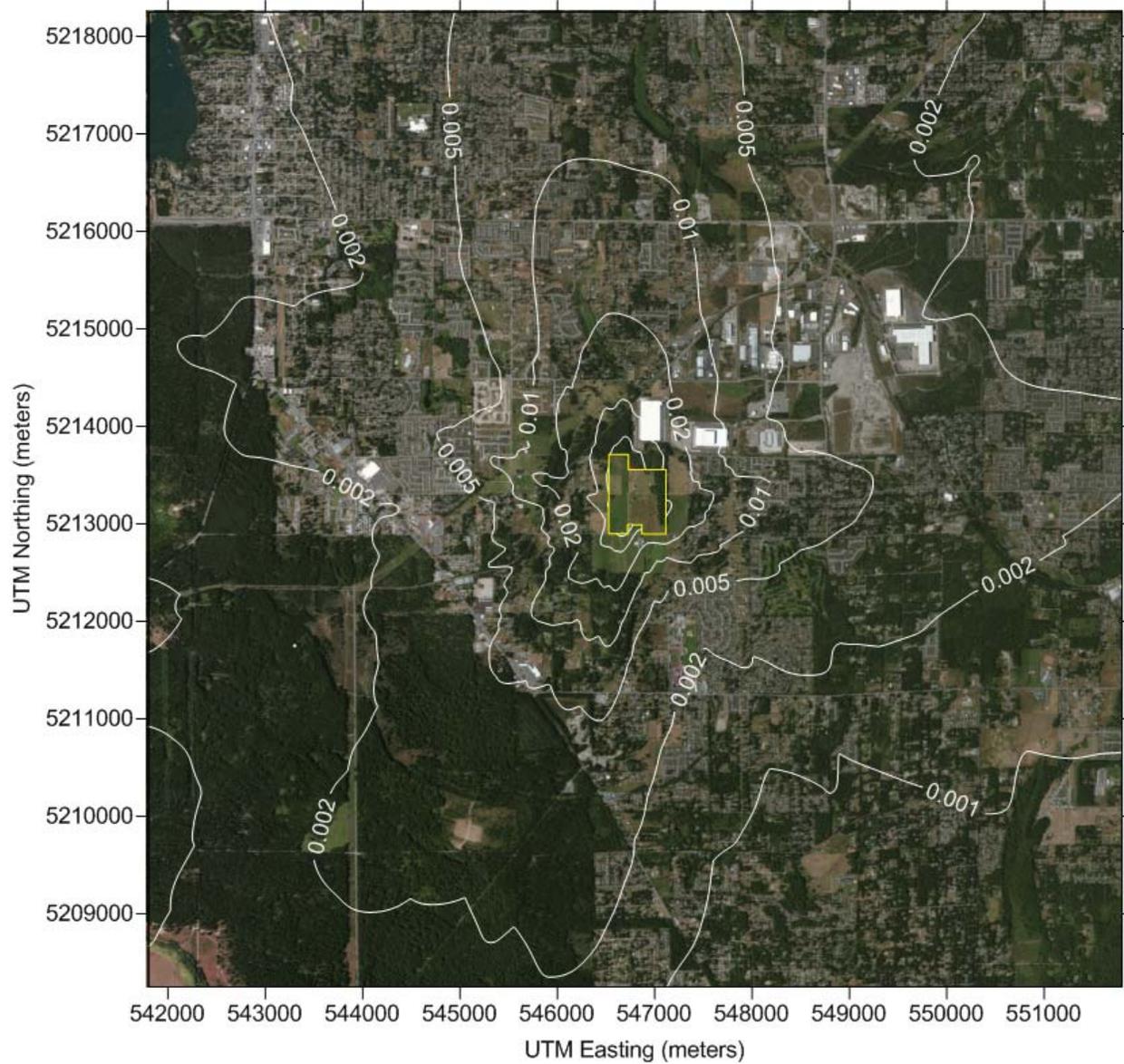


Figure 4-6: Max. Predicted Annual Average Formaldehyde Conc. ($\mu\text{g}/\text{m}^3$) – Domain

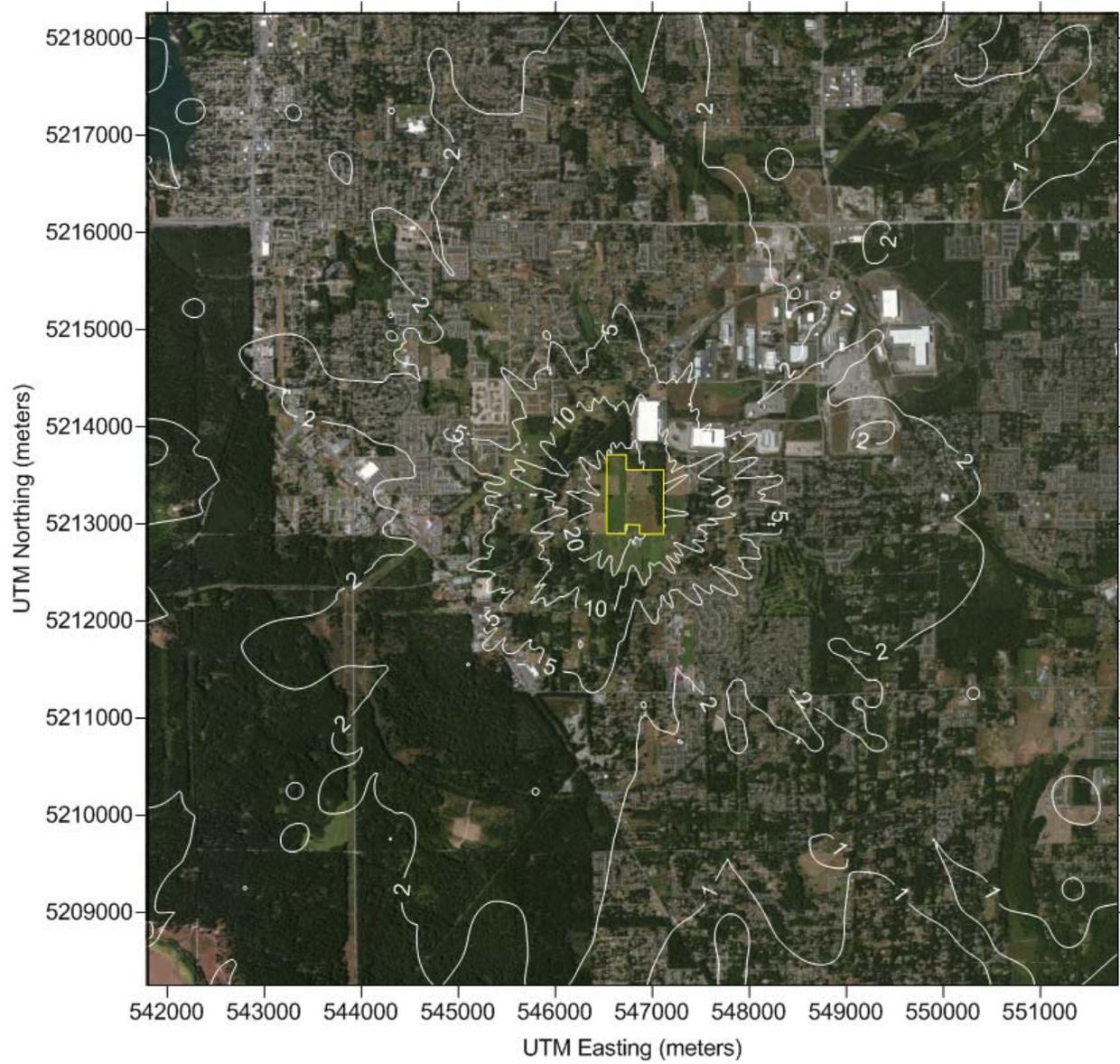


Figure 4-7: Max. Predicted 24-Hour Average Acetaldehyde Conc. ($\mu\text{g}/\text{m}^3$) – Domain

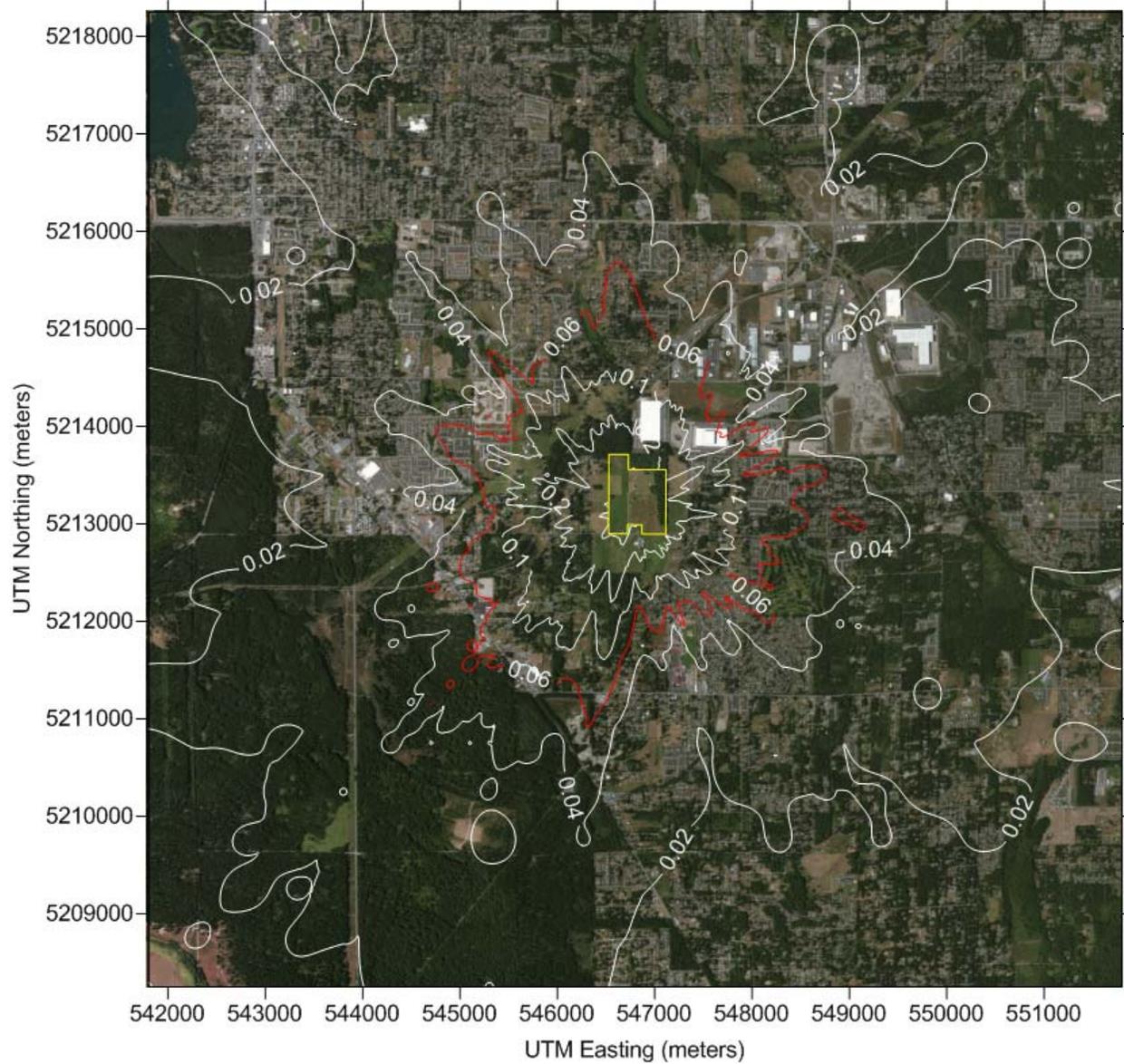


Figure 4-8: Max. Predicted 24-Hour Average Acrolein Conc. ($\mu\text{g}/\text{m}^3$) – Domain

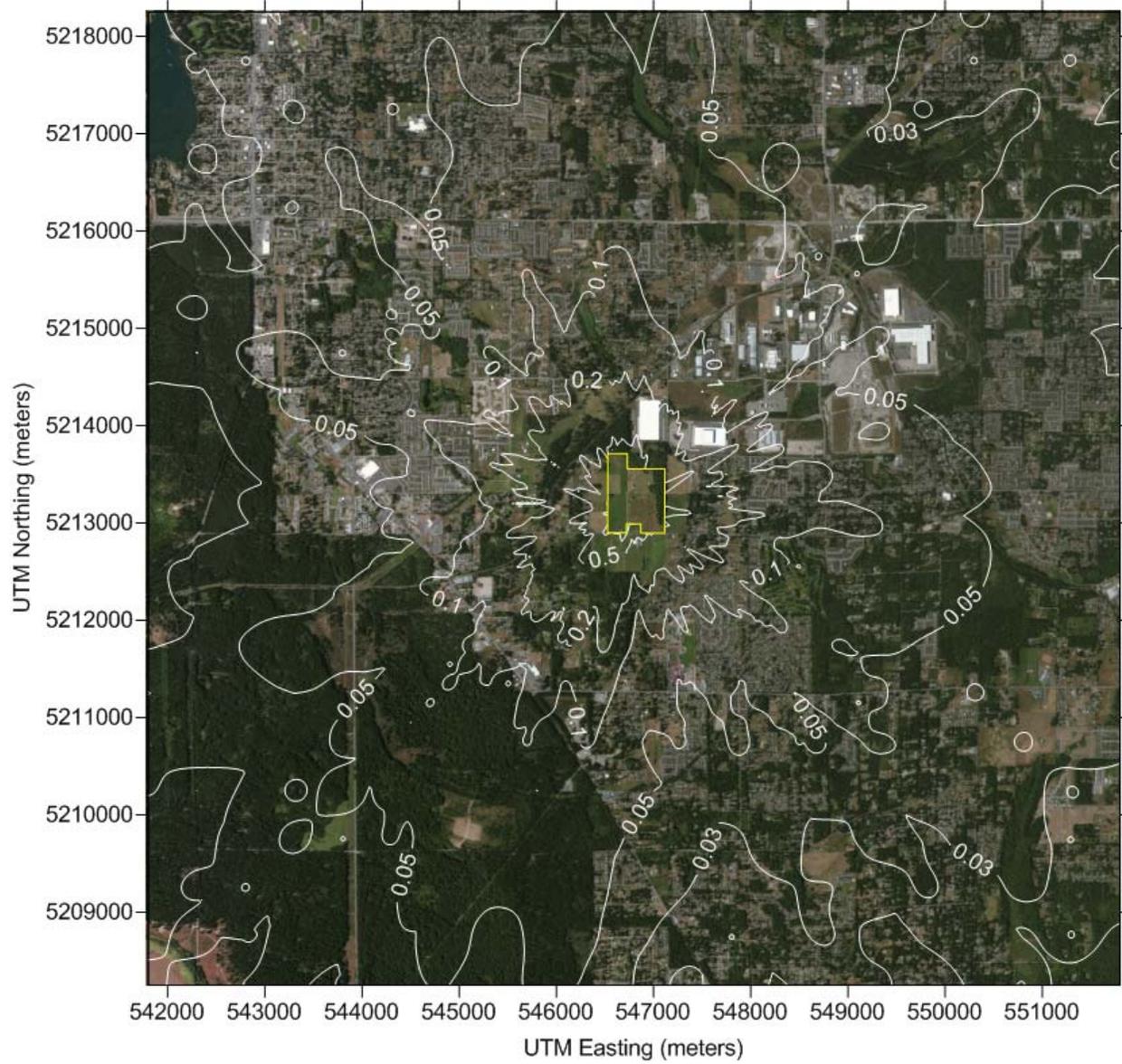


Figure 4-9: Max. Predicted 24-Hour Average Formaldehyde Conc. ($\mu\text{g}/\text{m}^3$) – Domain

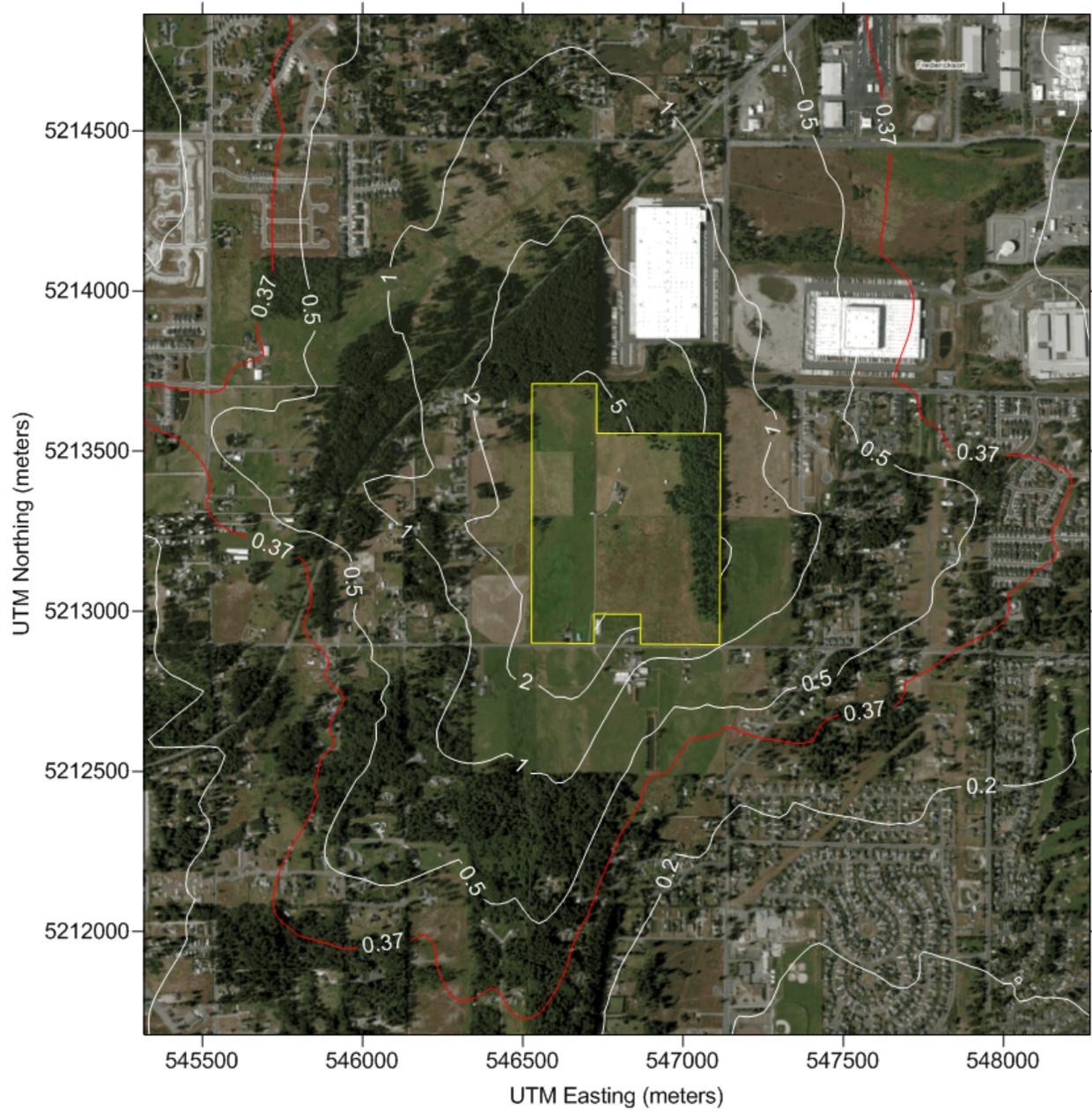


Figure 4-10: Max. Predicted Annual Average Acetaldehyde Conc. ($\mu\text{g}/\text{m}^3$) – Near

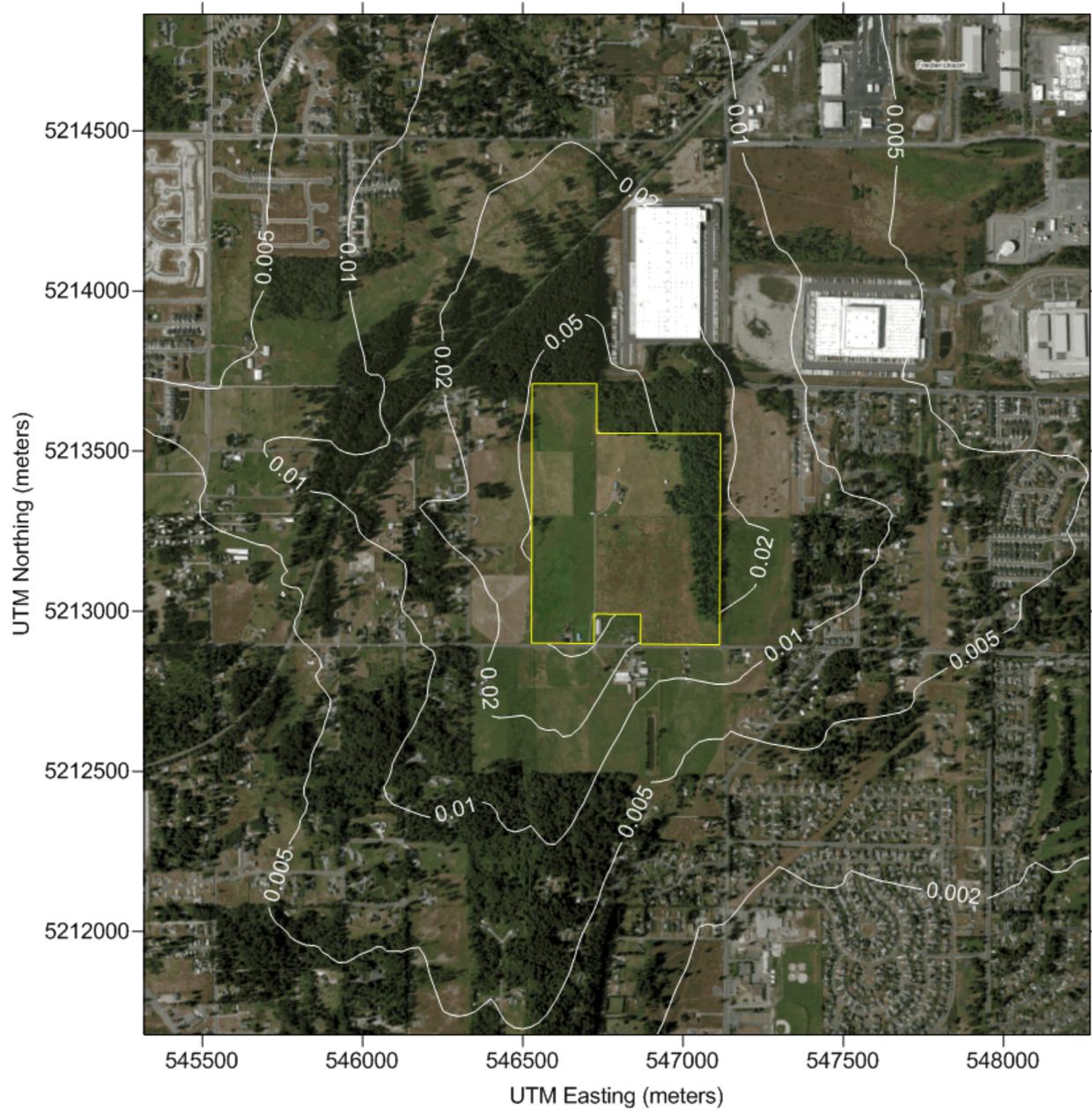


Figure 4-11: Max. Predicted Annual Average Acrolein Conc. ($\mu\text{g}/\text{m}^3$) – Near

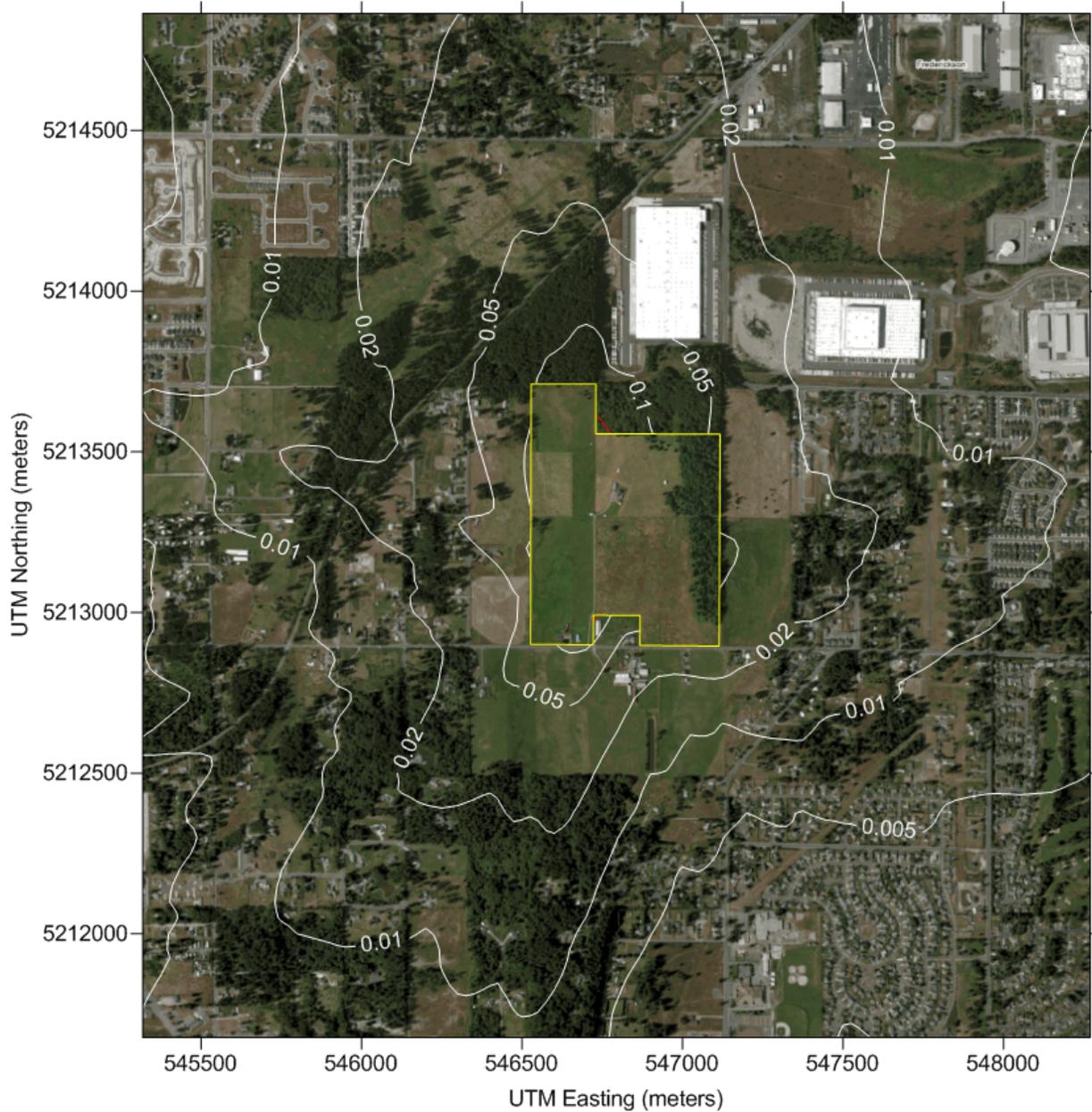


Figure 4-12: Max. Predicted Annual Average Formaldehyde Conc. ($\mu\text{g}/\text{m}^3$) – Near

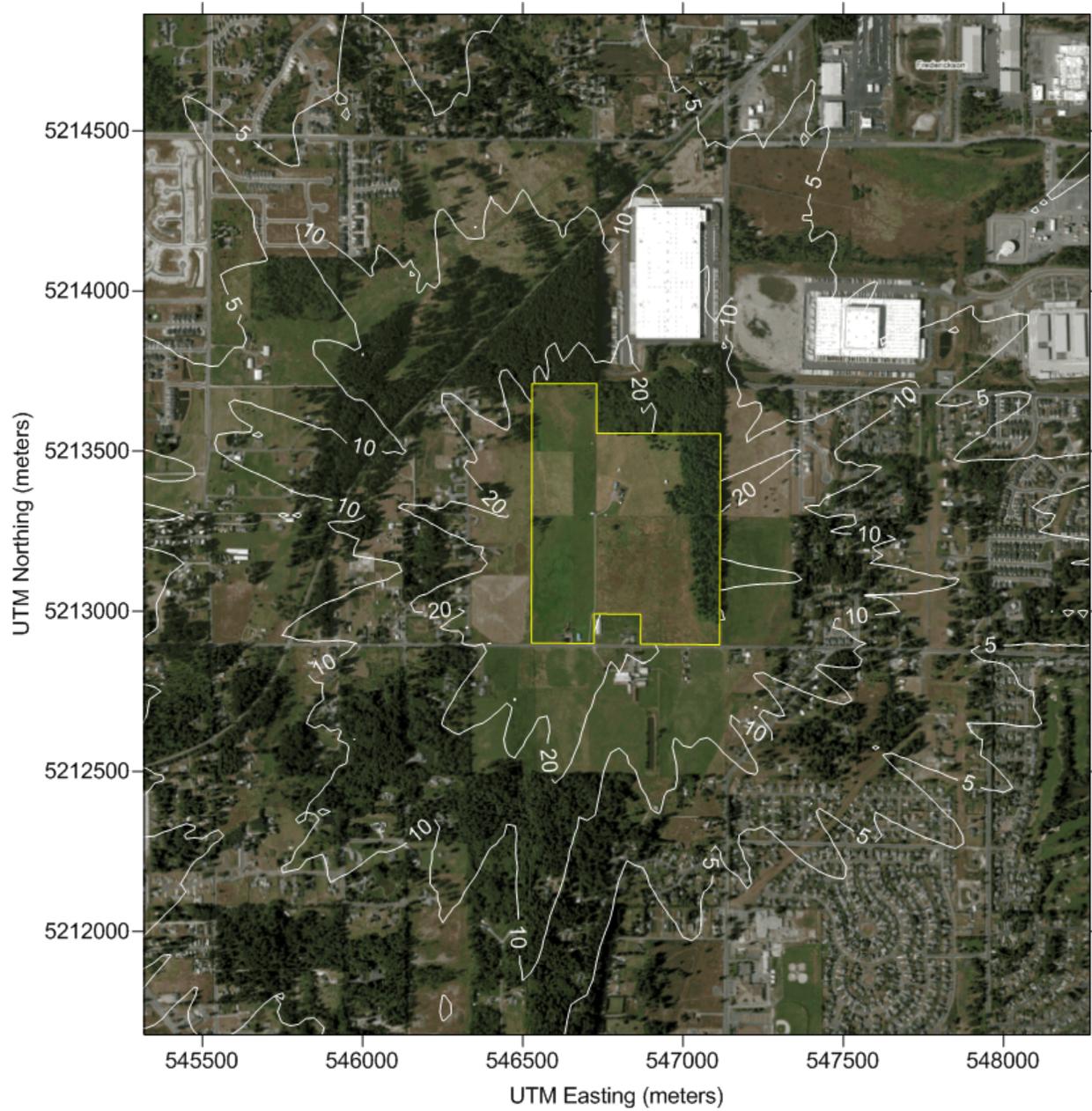


Figure 4-13: Max. Predicted 24-Hour Average Acetaldehyde Conc. ($\mu\text{g}/\text{m}^3$) – Near

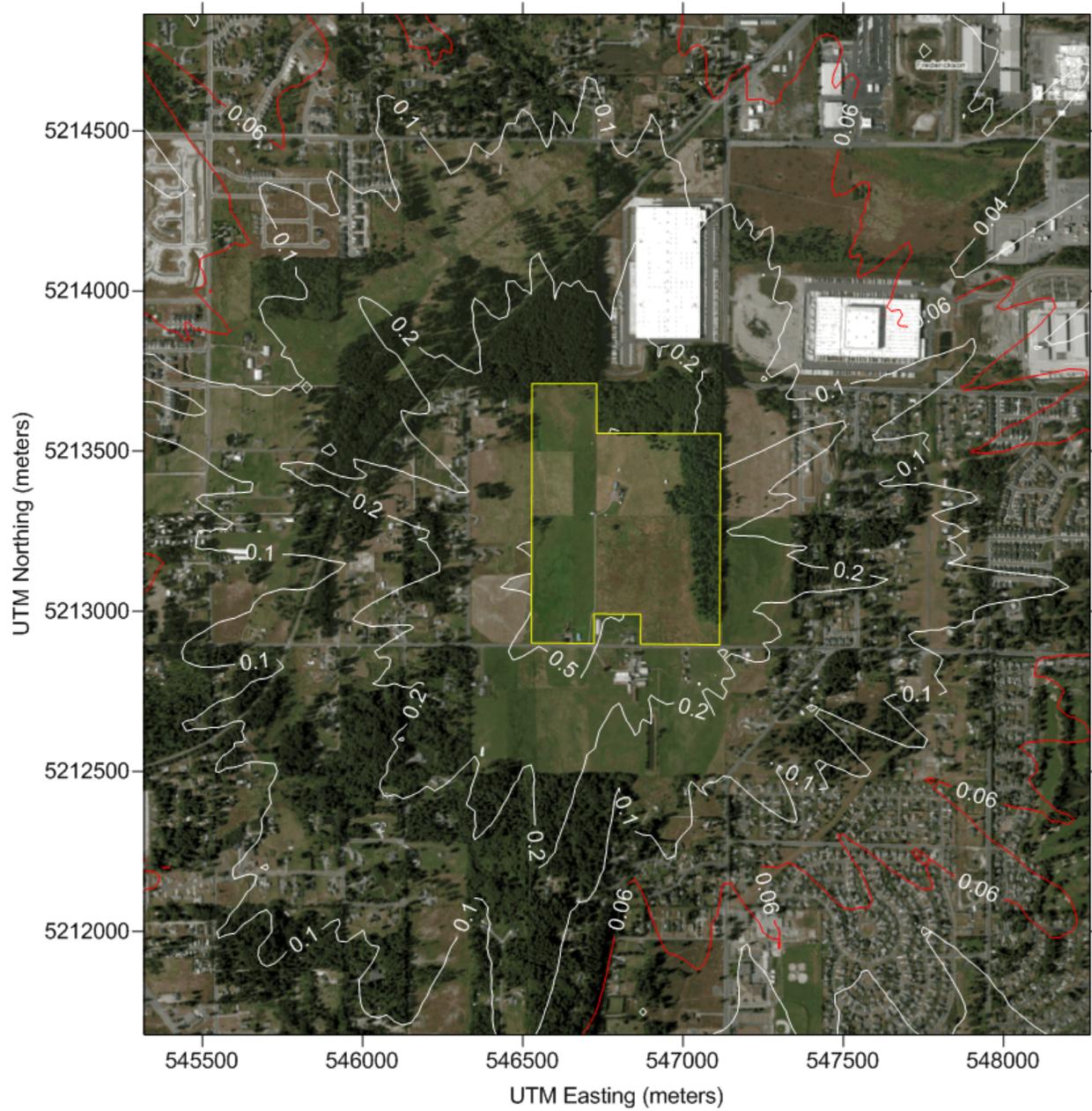


Figure 4-14: Max. Predicted 24-Hour Average Acrolein Conc. ($\mu\text{g}/\text{m}^3$) – Near

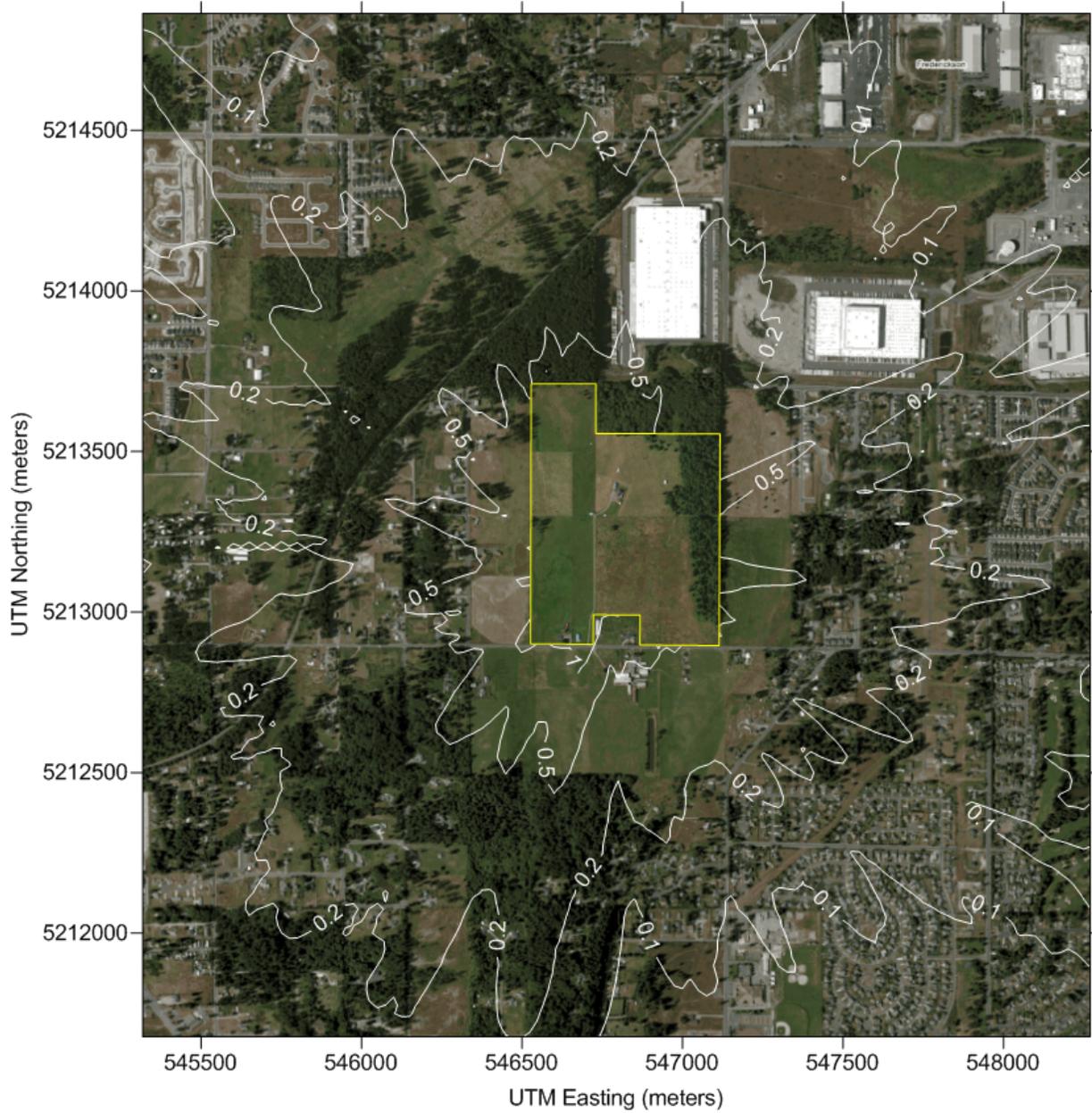


Figure 4-15: Max. Predicted 24-Hour Average Formaldehyde Conc. ($\mu\text{g}/\text{m}^3$) – Near

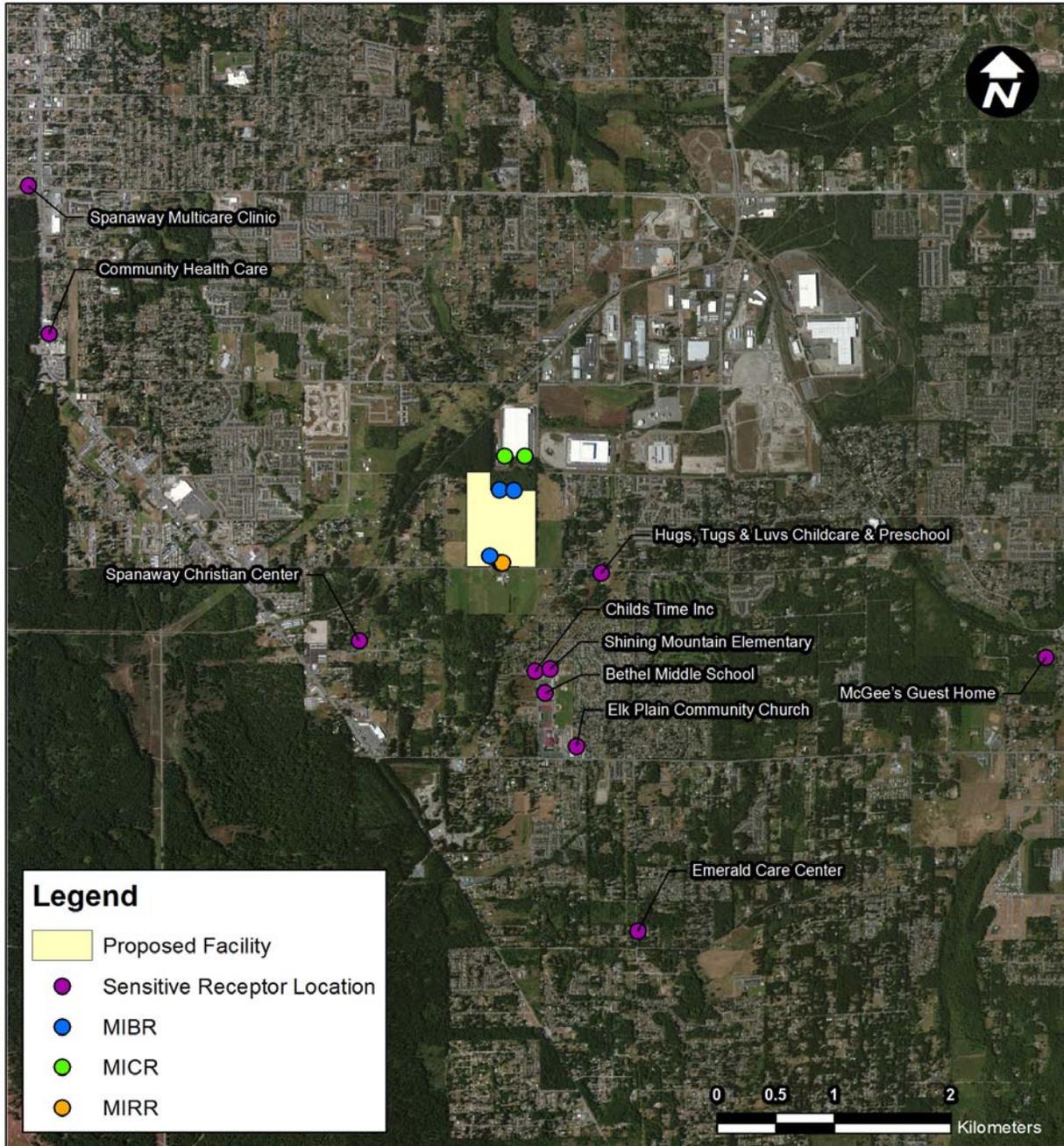


Figure 5-1: Locations of Sensitive Receptors Nearest to the Facility

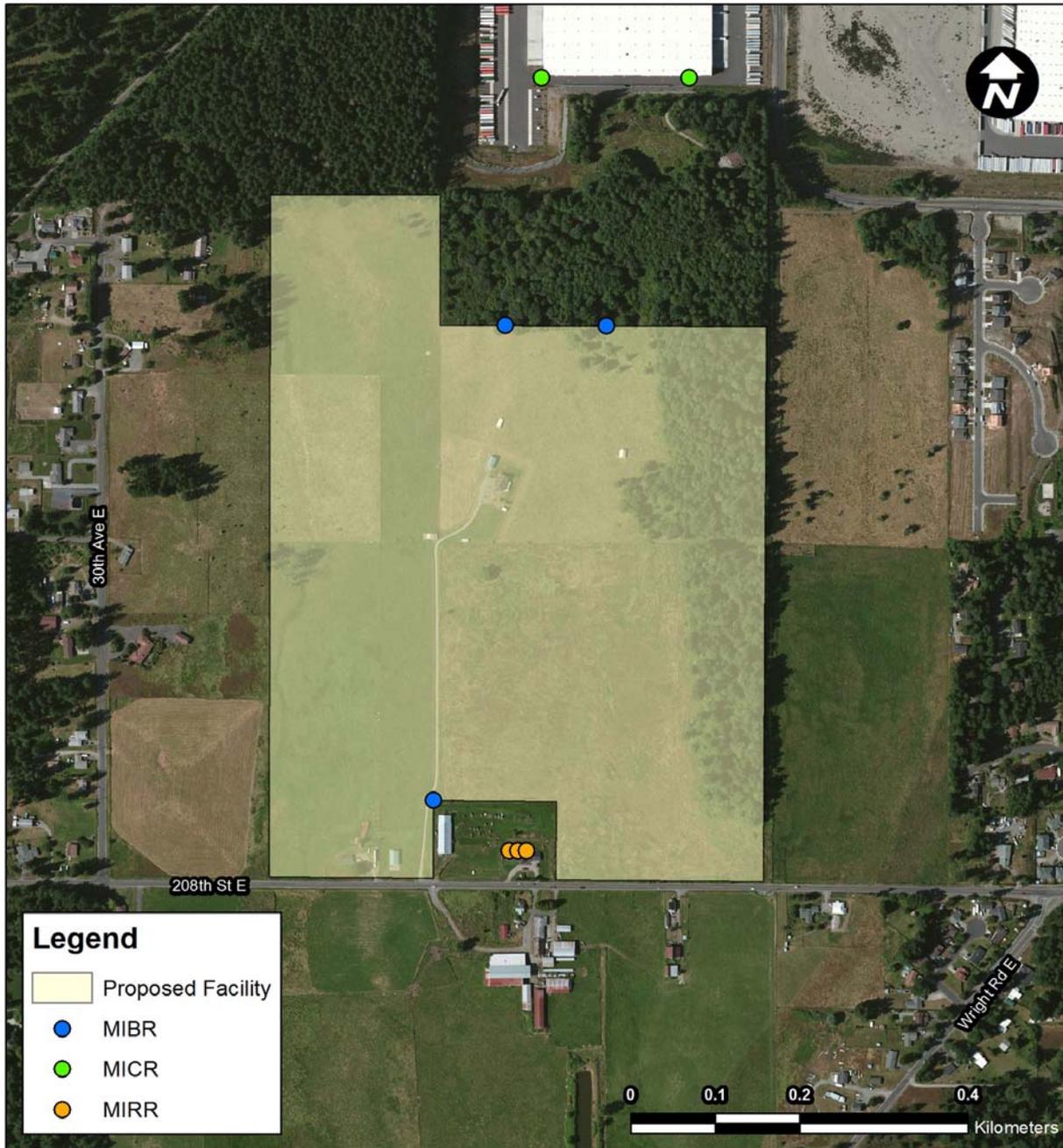


Figure 5-2: Locations of Receptors of Interest