Olympic Region

Regional Modeling and Health Risk Assessment

Prepared for

Olympic Region Clean Air Agency
2940 B Limited Lane NW
Olympia, WA 98502

by

Dillingham Software Engineering, Inc.
1025 Prospect St., Ste 320
La Jolla, CA 92037

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1 Introduction and Executive Summary

1.1 Project Overview

The Olympic Region Clean Air Agency (ORCAA) contracted with Dillingham Software Engineering, Inc. (DSE) to conduct a regional air quality health risk assessment analysis for the Olympic region. This report presents the results of that project.

The project objective is to identify key air pollution sources and pollutants impacting residential and geographic areas in the Olympic Region, and to generally assess the risk to the community from those sources. Ten study areas within the Olympic Region were analyzed. The work proceeded in three phases:

Phase 1: **Emission inventory.** Gather all of the emission data and source characteristics for each of the study areas.

Phase 2: **Dispersion modeling.** Conduct a dispersion modeling analysis for each of the study areas using the HARP program to determine the ground level concentrations on a grid encompassing the area.

Phase 3: **Risk analysis.** Perform health risk analysis for each of the study areas using the estimated ground level concentrations to compute cancer and chronic non-cancer health effects.

Source characteristics and emissions from commercial sources were provided to DSE by ORCAA. That data was converted to a format compatible with the HARP emission inventory database so that dispersion and risk analysis could be run. The commercial emission inventory database contains 107 release points from 53 different facilities.

Roadway vehicle emission sources include on-road diesel vehicles and on-road gasoline vehicles. Information on vehicle miles traveled by these sources and county-wide emissions was obtained from the Washington State Department of Ecology. Emissions were apportioned to freeways, arteries, collectors and local roads for modeling.

County-wide wood stove emissions were obtained from the Washington State Department of Ecology. Emissions were assumed to be proportional to the number of households in each area, as described using census data. For modeling, the wood stove emissions were apportioned to each census block group.

Air dispersion modeling was completed to calculate long-term average concentrations due to point source, roadway vehicles, and wood stoves. Long-term average concentrations were used to calculate cancer risk and chronic non-cancer risk following methods provided by the OEHHA *Air Toxics Hot Spots Program Risk Assessment Guidelines* [1].

Dispersion modeling was completed using the air dispersion module of the Hotspots Analysis and Reporting Program (HARP) Regional Batcher. HARP uses the ISCST3 dispersion model to obtain concentrations. Model inputs, including source emission rates, source parameters, receptor and terrain information, and other model options were input to HARP. Detailed discussion of dispersion modeling methods and results are provided in Section 4.

A regional health risk assessment was completed for point source, roadway vehicle, and wood stove impacts using the HARP software. All of the equations and chemical potency values for calculating health risks following OEHHA guidance are contained within the HARP program.

The concentration data from modeling were loaded into the HARP risk assessment module. 70 year adult resident cancer risk was calculated and reported for each study area. Non-cancer chronic non-cancer risks were also calculated following default OEHHA methodologies.

Risk results are described briefly in Section 5.2 and 5.4.

1.2 Report Organization

This report is organized as follows:

Section 2 – Olympic Region Description. This chapter gives a general description of the Olympic Region and the 10 study areas

Section 3 – Emissions Inventory. This chapter describes development of the Phase 1 emissions inventory database used to run the modeling and health risk analysis for point sources, roadway sources and wood stoves. The results of the emission database development are summarized.

Section 4 – Air Dispersion Modeling. This chapter describes the methods used to complete Phase 2 air dispersion modeling using the ISCST3 model and HARP, and summarizes the modeling results.

Section 5 –Health Risk Assessment. For Phase 3, health risk calculations were completed using HARP for air toxic emission sources in the Olympic Region. Cancer and chronic non-cancer health risk impacts are discussed. This section also contains detailed results, including risk contour maps, for each of the study areas

1.3 HARP Risk Assessment Software

All dispersion and risk analysis for this project was completed using the Hotspots Analysis and Reporting Program (HARP). HARP was developed by Dillingham Software Engineering, Inc. for the California Air Resources Board (CARB), and is the standard software distributed by CARB for risk analysis in California.

The HARP program uses the standard Industrial Source Complex Short Term (ISCST3) dispersion model developed by the U.S. EPA to perform the dispersion calculations. Information on the ISCST3 program can be obtained from EPA's SCRAM web site at the following URL:

http://www.epa.gov/scram001/tt22.htm

The HARP risk analysis algorithms follow the procedures developed by the California Office of Environmental Health Hazard Assessment (OEHHA). The procedures are documented in a four-volume guidance document published by OEHHA. The guidance manual for preparation of health risk assessments [1] can be downloaded from the OEHHA web site at the following URL:

http://www.oehha.ca.gov/air/hot_spots/HRSguide.html

The same web site contains reports and data on chemical cancer potency factors and reference exposure levels for chronic non-cancer and acute health effects.

Background information on the HARP program can be found on either the CARB web site:

www.arb.ca.gov/toxics/harp/harp.htm

or the Dillingham Software Engineering web site:

www.DillinghamSoftware.com

Public domain versions of the software can be downloaded from either of these sites. The public domain version of HARP is the “standard” version, which was developed for the CARB Stationary Source Division (SSD).

The version used for this project is a more advanced version of HARP that is being developed by Dillingham Software Engineering, Inc. for the CARB Planning and Technical Support Division (PTSD). This version is known as the HARP Regional Modeler (a.k.a. the HARP Batch Processor). The HARP Regional Modeler is able to handle a much larger number of emission sources, and perform the dispersion and risk analysis incrementally. The HARP Regional Modeler is not yet publicly available. A description of the regional modeling process flow is given in Section 5.1.1.

1.4 Acronyms

The following is a list of common acronyms used in the report:

USGS	U.S. Geological Survey (the source of terrain elevation data).
GLC	Ground level concentration. The concentration of a particular chemical at ground level at some receptor location, usually expressed in micrograms/cubic meter.
DEM	Digital elevation model. A standard file format used for storing terrain elevation data. This file format can be obtained from USGS and can be read by HARP when building the dispersion model.
ISC / ISCST3	Industrial Source Complex Short Term. A computer program developed by the U.S. EPA for performing dispersion calculations.
HQ	Health quotient. The ratio of dose to reference exposure level (for oral pathways) or ground level concentration to reference exposure level (for inhalation pathway). For a more detailed explanation refer to section 5.1.1.4.
HI / HHI	Health hazard index. The sum of the HQs across all chemicals for a particular toxicological endpoint. For a more detailed explanation refer to section 5.1.1.4.
REL	Reference exposure level. A value of ground level concentration (for chronic inhalation effects or acute effects) or dose (for chronic oral effects) defined such that levels of exposure below the REL are considered to be safe and levels of exposure above the REL and not safe for regulatory purposes. For a more detailed explanation refer to section 5.1.1.4.
PMI	Point of maximum impact. A location where the potential health impact (computed risk) is highest. Defining the PMI does not imply that there are necessarily real human receptors at the location. The PMI is based on the potential risk if there were humans present.

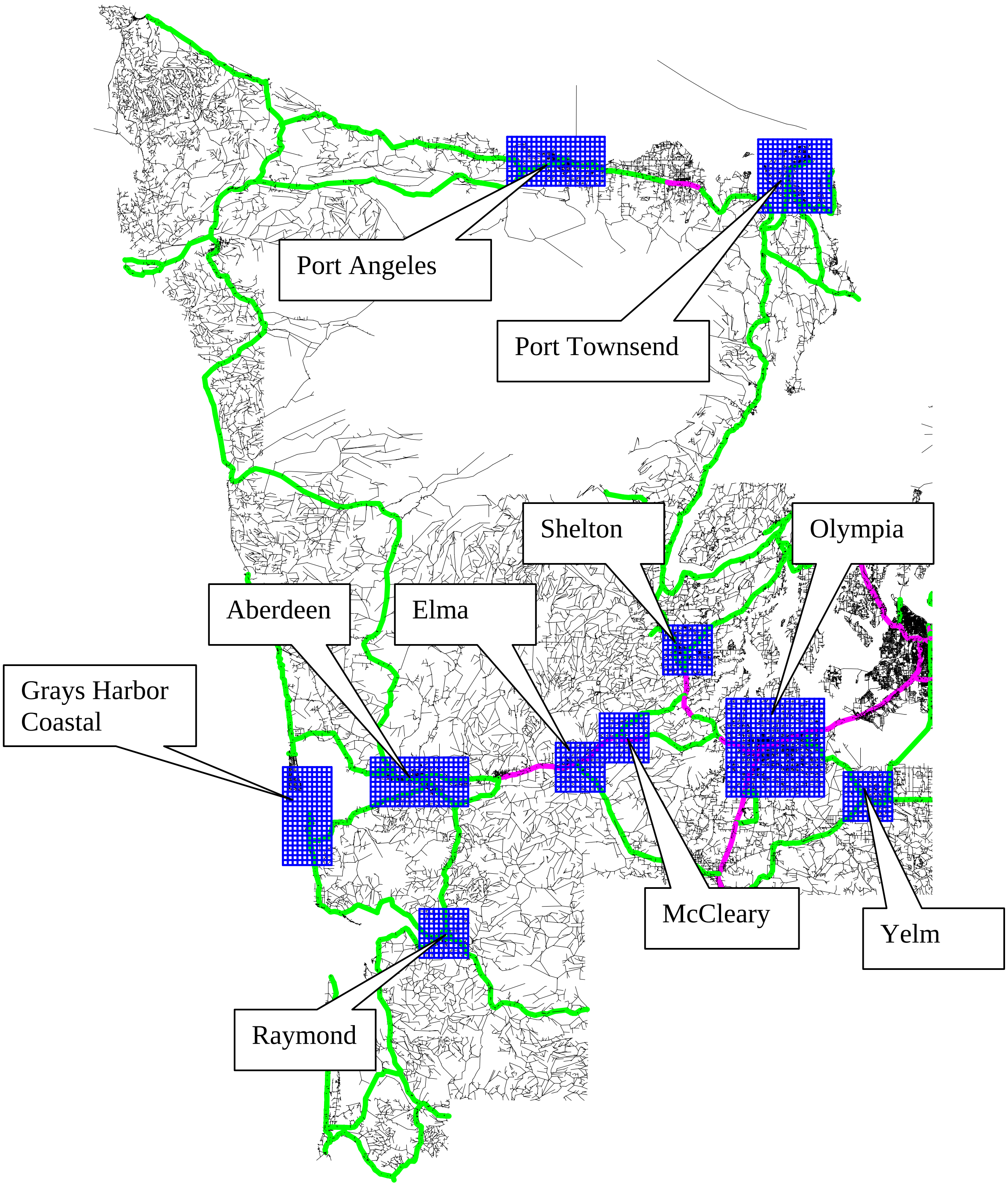
2 Olympic Region Description

This section provides a description of the Olympic Region. It provides information on the air quality study setting, air emission sources that are important, land use in the region and meteorology.

2.1 Geography

Figure 2-1 County map of the Olympic Region.

Figure 2-2. Ten Olympic Region study areas.



2.2 Air Emission Sources

This project addresses four types of emission sources:

1. **Commercial sources** (also called point sources in this report). These are attributed to businesses that emit pollutants into the atmosphere on a regular basis.
2. **On-road diesel.** These are mobile sources (trucks and cars) that are diesel powered.
3. **On-road gasoline**. These are mobile sources (trucks and cars) that are gasoline powered.
4. **Wood stoves and fireplaces.** Given the relatively cool maritime climate, wood stoves may be frequently used for both pleasure and comfort heating in the residential areas.

Although not included in this study, port emissions from ships and mobile equipment may be important to health impacts in the region. Ships have engines that may burn such "dirty" fuels as bunker fuel. Ships idling in ports or moving along the coastlines may emit pollutants that affect coastal communities.

2.3 Meteorology

Meteorology varies from one study area to the next. The meteorology that was assumed for this project is discussed in detail in section 4.1.3.

3 Emissions Inventory

Phase 1 of the project included development of an air emissions inventory database for the Olympic Region. The emissions inventory was used to complete HARP air dispersion modeling and health risk assessment calculations. This section describes the methods used to collect and develop the emission inventory data for use with HARP.

3.1 Emission Inventory Development Methods

To complete air quality modeling and risk assessment calculations using HARP for stationary sources in the Olympic region, the following information was required:

1) Source location coordinates, including coordinate system information
2) Emissions data, including pollutant name, pollutant CAS number, annual emissions (lb/yr)
3) Source type (point, volume, area)
4) Modeling source parameters (stack height, diameter, flow rate, temperature, geometry and dimensions of area and volume sources)
5) Operating schedule (hrs/day)

This information was developed for three emission categories:
1) Commercial sources (point sources)
2) Roadway vehicle sources (diesel and gasoline)
3) Wood stoves and fireplaces.

A discussion on each category is provided below.

3.1.1 Point Sources

The point source emissions data was provided by ORCAA. All of the point source emissions data used in this report is for the year 2002. Data was compiled from existing permits and databases where it was available. In some cases the ORCAA staff undertook to gather new data where it seemed appropriate, and to make engineering estimates of parameters that were not readily available. Data was provided to DSE staff in the form of MS Access data files. These data were converted to a Microsoft database format. A conversion program was created to import the ORCAA data into the HARP database, making the necessary unit conversions and reorganizing the data to fit the HARP database structure. The data was checked for relational integrity. DSE did not independently verify the correctness of the emissions and source parameters, though we did check that the parameters were sensible. Data that seemed outside of a reasonable range were reported back to ORCAA to be verified. A few data entry errors were located and corrected.

3.1.2 Roadway Vehicle Sources

This section describes the methods for developing the emission inventory and source characteristics for roadway emissions.

County-wide total roadway vehicle emissions were obtained from the Washington State Department of Ecology and are shown in Table 3-1. In order to model the dispersion and health effects of roadway vehicle emissions, the county-wide emissions of each chemical must be distributed spatially across the study area. This necessitates determining the geographic locations of the roadway sections and creating model emission sources at those locations, each of which has the correct spatial extent and location, and emission rates proportional to the vehicle emissions on that roadway section.

Data on vehicle miles traveled (VMT) was obtained from the Department of Ecology for each of the counties in the Olympic region, broken down into four types of roadways: freeways, arteries, collectors and local roads. For the purposes of our study we define these roadway types according to the categories of roads defined in the Census Bureau Tiger data definitions. Tiger is an acronym for Topologically Integrated Geographic Encoding and Referencing. The Tiger data assigns to every road a Census Feature Class Code (CFCC), which categories the type of road. We assigned each of the four road types used referred to in the Dept. of Ecology database to ranges of CFCC codes according to the following table.

Road Type	***CFCC codes***	***Description***
Freeway	A11 - A18	Primary road with limited access or interstate highway
Artery	A21 – A28	Primary road without limited access
Collector	A31 – A38	Secondary and connecting road
Local Road	A41 – A74	Local neighborhood and rural road

Using these definitions we were able to use the Tiger data to locate the end points of every road in the study areas and classify it by type. Emissions were assumed to be proportional to vehicle miles traveled, and vehicle miles traveled were assumed to be proportional to total roadway length. However, it was important to account for different roadway types because the VMT is very different for each roadway type, and roadway types are different between counties.

The total length of each roadway type in each county was computed using the HARP program and is tabulated in Table 3-1. The roadway data used for this calculation is the Census Bureau Tiger data, which is the same data used by HARP to draw street maps. This data shows that there are many more miles of local roads than freeways, which is not a surprise. Because the local roads represent the majority of the roadway length but only a small fraction of the vehicle miles traveled, it follows that the emissions per mile from local roads must be very small compared to freeways.

If fractional VMT is divided by the total roadway length and emissions are assumed to be proportional to VMT, then fractional emissions per km for each roadway type can be estimated as shown in Table 3-1. The term “fractional emissions” means the fraction of total county-wide emissions of any chemical that are emitted from a one kilometer section of roadway.

The algorithm for distributing emissions in the model is as follows. For freeways, arteries and collectors roadways are divided into sections (also called links) such that the length to width ratio of each link does not exceed 100:1. The limitation of 100:1 follows CARB policy and is based on the limitations of the ISCST3 dispersion modeling program. For each of the links an area source is created that is a rotated rectangle aligned with the roadway. Since data on individual roadway widths is not available, it was assumed that all roadways are 48 feet wide. For each of these area sources we compute the emissions by multiplying the fractional emissions (Table 3-1) by the length of the link. The area source and geometry and emissions are then added to the HARP emission inventory database. The release of emissions from roadway vehicles is assumed to be at ground level.

For local roads, a slightly different modeling approach was used. The study area was divided into one km grid cells. For each grid cell, the total length of local roads was computed and multiplied by the fractional emissions to obtain the actual emission from that cell. Then, an area source was created that is a one km square rectangle at that location. The reason for this different approach is that the number of area sources that would be required to model each and every local road is prohibitively large. Because the local roads are close together and have relatively low emission rates per km we believe that aggregating them together into larger cells is justified. In contrast, the freeways, arteries and collectors are discrete lines of high emissions which need to be modeled individually to capture the spatial distribution of the risk.

The procedure described above will ensure that the total emissions from all the cells and roadway links across the county will exactly equal the county-wide total emissions for each chemical (i.e. it will conserve mass). Only cells and links that fall within the study area were actually included in the analysis. The result is that the emissions from all the cells are distributed spatially in proportion to the vehicle miles traveled and are concentrated around those road types that produce the most emissions (freeways and arteries) on the basis of VMT.

The two assumptions can be summarized as follows:

1) emissions are proportional to VMT for each roadway type

total county-wide emissions from each roadway type =

$$\text{total county-wide emissions} \times \frac{\text{VMT for this roadway type}}{\text{total county VMT for all roadways}}$$

2) VMT is proportional to roadway length within any given area

emissions for one cell for each roadway type =

$$\text{total county-wide emissions roadway type} \times \frac{\text{length of roadway type in cell}}{\text{total county-wide length of roadway type}}$$

What are the weaknesses of this approach? Not all roadways of a particular type have the same VMT. A freeway in downtown Olympia will have a higher VMT than a freeway passing through a rural area. A local road in the country will have a lower VMT than a local road in a dense residential area. The only way to overcome this deficiency would be to incorporate data on VMT for individual roadways, which is not available at this time.

Table 3-1. Vehicle miles traveled, and calculation of emission fractions per km on the four roadway types.

Vehicle miles traveled

County	***freeway***	***arteries***	***col***	***local***	***total***
Clallam	33.592	751.714	347.646	89.599	1222.552
GraysHarbor	172.753	1171.413	371.902	120.925	1836.993
Jefferson	0.000	593.181	197.074	78.148	868.403
Mason	0.000	742.680	343.328	59.497	1145.505
Pacific	0.000	415.834	153.072	33.557	602.464
Thurston	2532.932	1888.706	814.250	442.231	5678.119
TOTAL	2739.277	5563.529	2227.272	823.957	11354.035

Fractions of VMT by roadway type

	freeway	***arteries***	***collectors***	***local***	***total***
Clallam	0.027	0.615	0.284	0.073	1.000
GraysHarbor	0.094	0.638	0.202	0.066	1.000
Jefferson	0.000	0.683	0.227	0.090	1.000
Mason	0.000	0.648	0.300	0.052	1.000
Pacific	0.000	0.690	0.254	0.056	1.000
Thurston	0.446	0.333	0.143	0.078	1.000

Roadway length (km) by roadway type

County	***freeway***	***arteries***	***collectors***	***local***	***total***
Clallam	6.584	137.598	141.148	4768.711	5054.041
GraysHarbor	33.538	178.274	133.523	5847.405	6192.740
jefferson	0.000	119.033	83.051	2678.243	2880.327
mason	10.552	54.775	128.575	4106.918	4300.820
pacific	0.000	105.063	148.626	3287.548	3541.237
thurston	56.458	20.598	89.339	4201.814	4368.209

Fraction of roadway length by roadway type

	freeway	*arteries*	*collectors*	*local*	*total*
Clallam	0.0013	0.0272	0.0279	0.9435	1.0000
GraysHarbor	0.0054	0.0288	0.0216	0.9442	1.0000
Jefferson	0.0000	0.0413	0.0288	0.9298	1.0000
Mason	0.0025	0.0127	0.0299	0.9549	1.0000
Pacific	0.0000	0.0297	0.0420	0.9284	1.0000
Thurston	0.0129	0.0047	0.0205	0.9619	1.0000

Fraction of county emissions per km of roadway length

County	*freeway*	*arteries*	*collectors*	*local*
Clallam	4.173E-03	4.469E-03	2.015E-03	1.537E-05
GraysHarbor	2.804E-03	3.577E-03	1.516E-03	1.126E-05
Jefferson	0.000E+00	5.739E-03	2.733E-03	3.360E-05
Mason	0.000E+00	1.184E-02	2.331E-03	1.265E-05
Pacific	0.000E+00	6.570E-03	1.710E-03	1.694E-05
Thurston	7.901E-03	1.615E-02	1.605E-03	1.854E-05

Figure 3-1. Roadway sources in the Port Angeles study area. The square magenta symbols mark the locations of the end points of artery and collector links. Arteries are magenta and collectors are green. There are no freeways in Port Angeles (See enlargement in next figure)

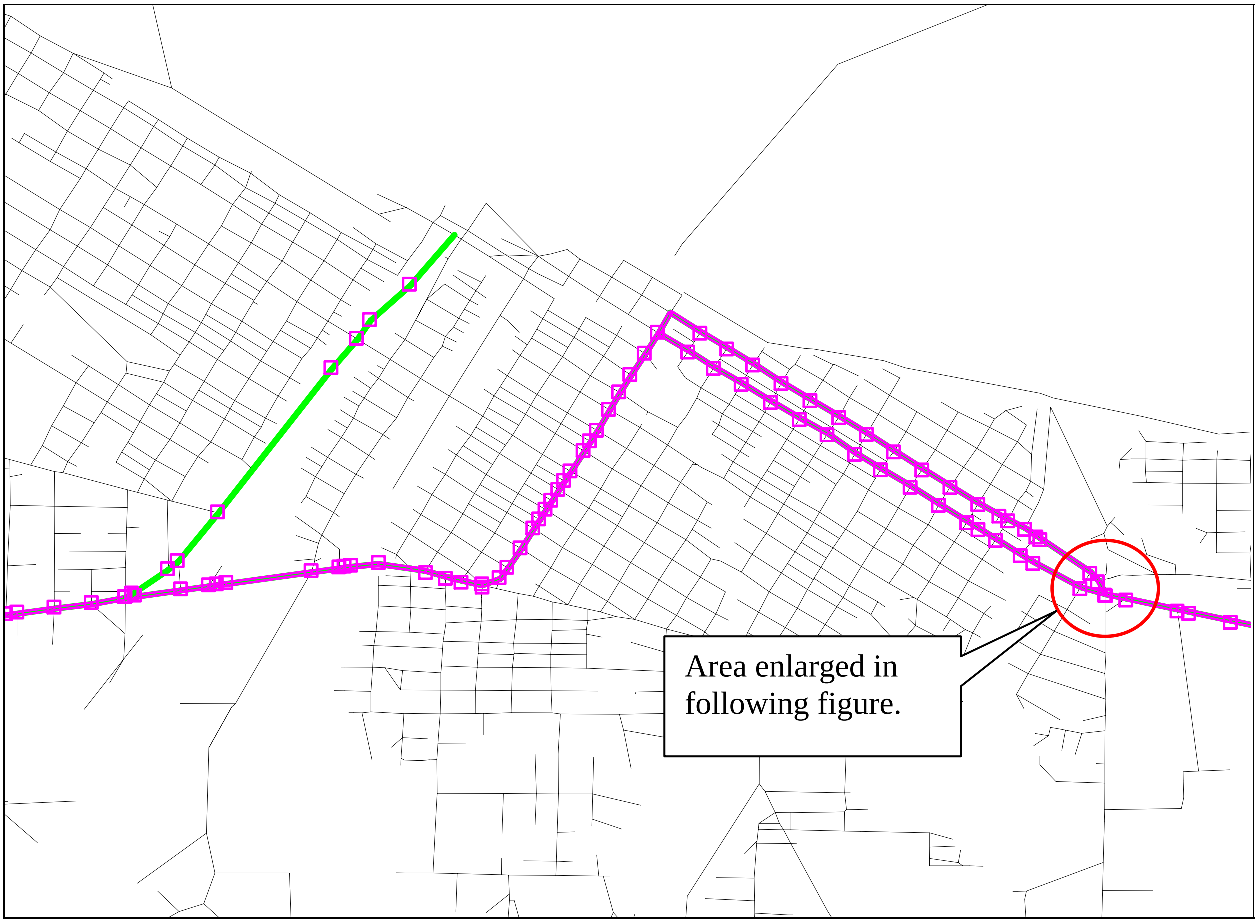


Figure 3-2 Example of area sources used to model roadway vehicle emissions and dispersion. Each of the magenta rectangles represents an area source used to model one link of the roadway. Links are designed to ensure that the length to width ratio does not exceed 100:1.

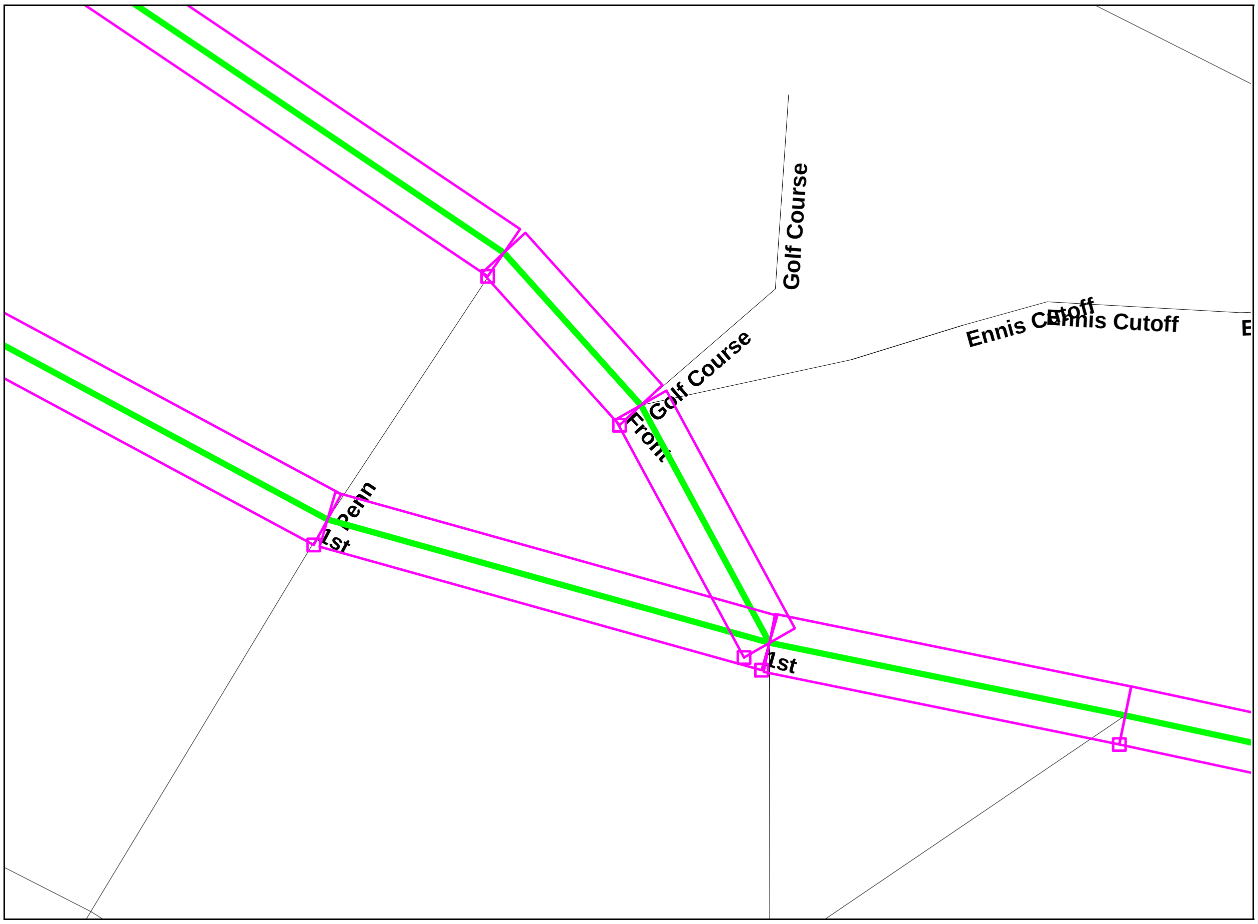
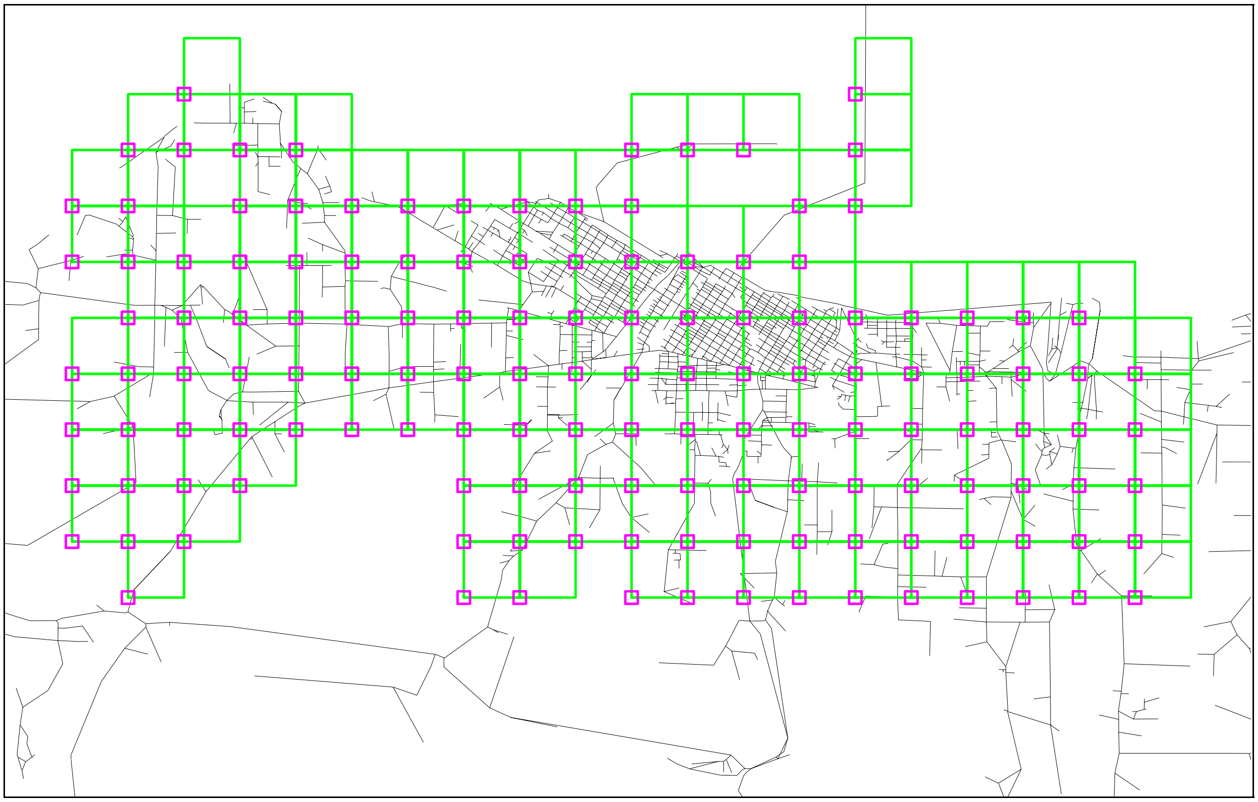


Figure 3-3. This figure shows the locations of modeled emission sources representing local roads for diesel and gasoline sources for Port Angeles. Each source is a 1 km square whose emissions are proportional to the total estimated vehicle miles traveled within that area.



3.1.3 Wood Stoves

This section describes the method used to develop the emission inventory for wood stoves (including fireplaces) and the physical parameters of the wood stove emission sources that were used in the model.

County-wide emissions were obtained from the Washington State Department of Ecology in a spreadsheet format. Emissions from wood stoves and other non-point sources are summarized in a published report from the Washington Department of Ecology [3]. The emissions data were converted into a Microsoft Access database so that the data could be more easily manipulated programmatically.

In order to model the dispersion and health effects of wood stove emissions, the county-wide emissions of each chemical have to be distributed spatially across the study area. The means determining the geographic locations of the wood stoves and creating model emission sources, each of which has the correct spatial extent and location and emission rates proportional to the number of wood stoves in that area.

Wood stove emissions from any area are assumed to be proportional to the number of households in that area that use wood as a heating fuel. The U.S. Census Bureau publishes data on the number of households within each census block group that use wood fuel for heating. These data also include the geographic location and area of each of these census block groups. A census block group is an area that is smaller than a census tract and typically encompasses several city blocks.

For each of these census block groups, an area source was created for the purpose of dispersion modeling. Each area source is a square having an area equal to the area of the census block group and a centroid located at the centroid of the census block group. For each area source the chemical emissions were computed by taking the total county-wide emissions and multiplying by the ratio of the number of wood burning households within that area to the total number of wood burning households in the county.

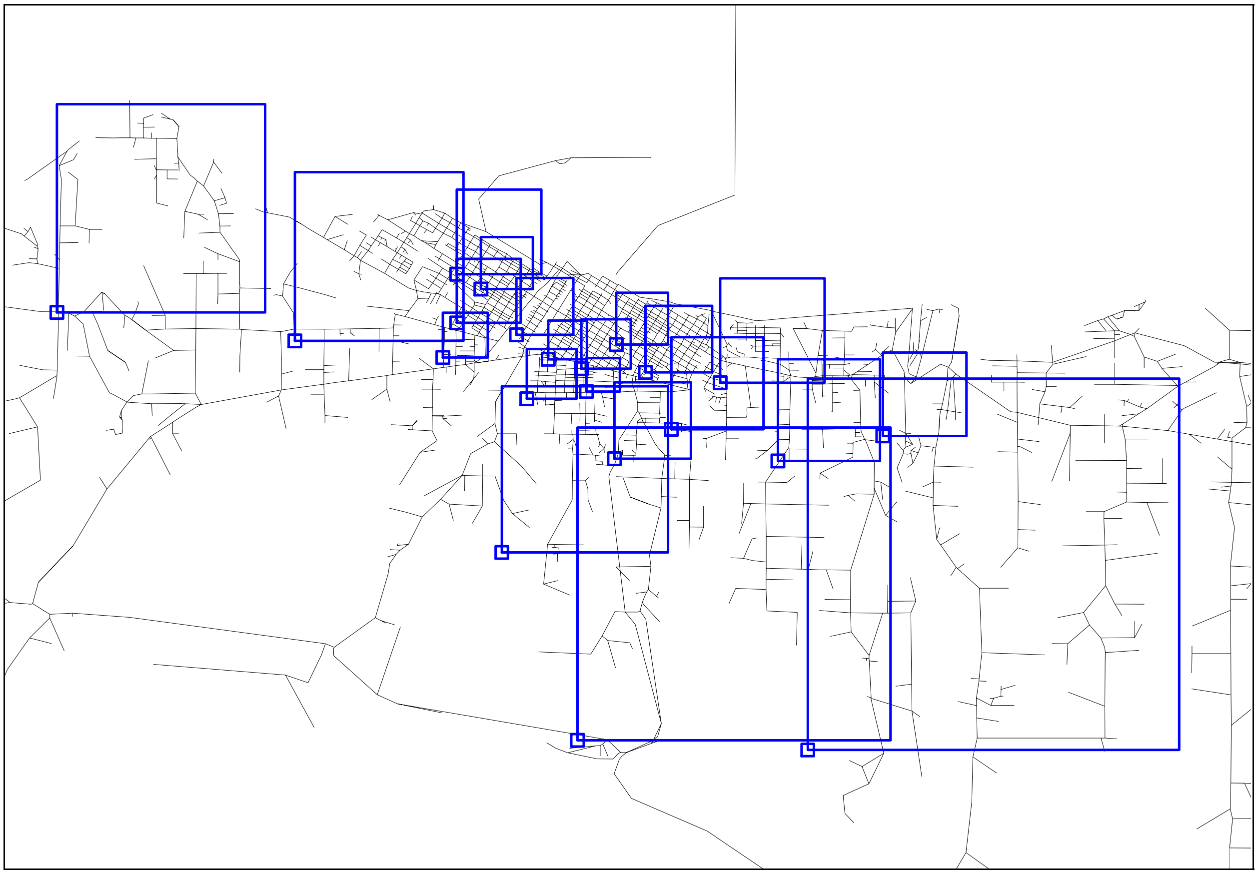
The height of release of the emissions from these area sources is assumed to be 20 feet.

This approach to modeling wood stoves will approximately capture the spatial distribution of the wood stove emissions on a regional scale, but there are obvious limitations. We have assumed that the distribution of wood stove emissions is uniform within the area represented each of the census block groups. Therefore we have neglected any finer scale variations of the emissions. In reality, one block may have more wood stoves than an adjacent block, and we have not wayh to account for this smaller scale variation. Since we are modeling each census block group as a rectangular area source, we are also not accounting for the details of the shape of the census boundaries. But we are modeling the emissions in such a way that the centroid locations and area of each source is the same as that of the census block group, and this is believed to provide a reasonable approximation to the spatial distribution of wood stove emissions on a large scale.

Appendix 7.1 lists the census data used to develop the model for distributing wood stove emissions.

The following figure shows an example (for Port Angles) of the area sources used to model wood stove emissions.

Figure 3-4. Locations and Sizes of Wood Stove Area Sources. Each blue rectangle shows the location of one of the census block groups where wood stoves are present. Each of these is modeled as an area sources having an area that is equal to the area of that census block group and a location whose centroid matches the census block group centroid. The emissions from each of these sources is a fraction of the total county emissions proportional to the number of households in that census block group that use wood as a heating fuel.



3.2 Emissions Inventory Summary

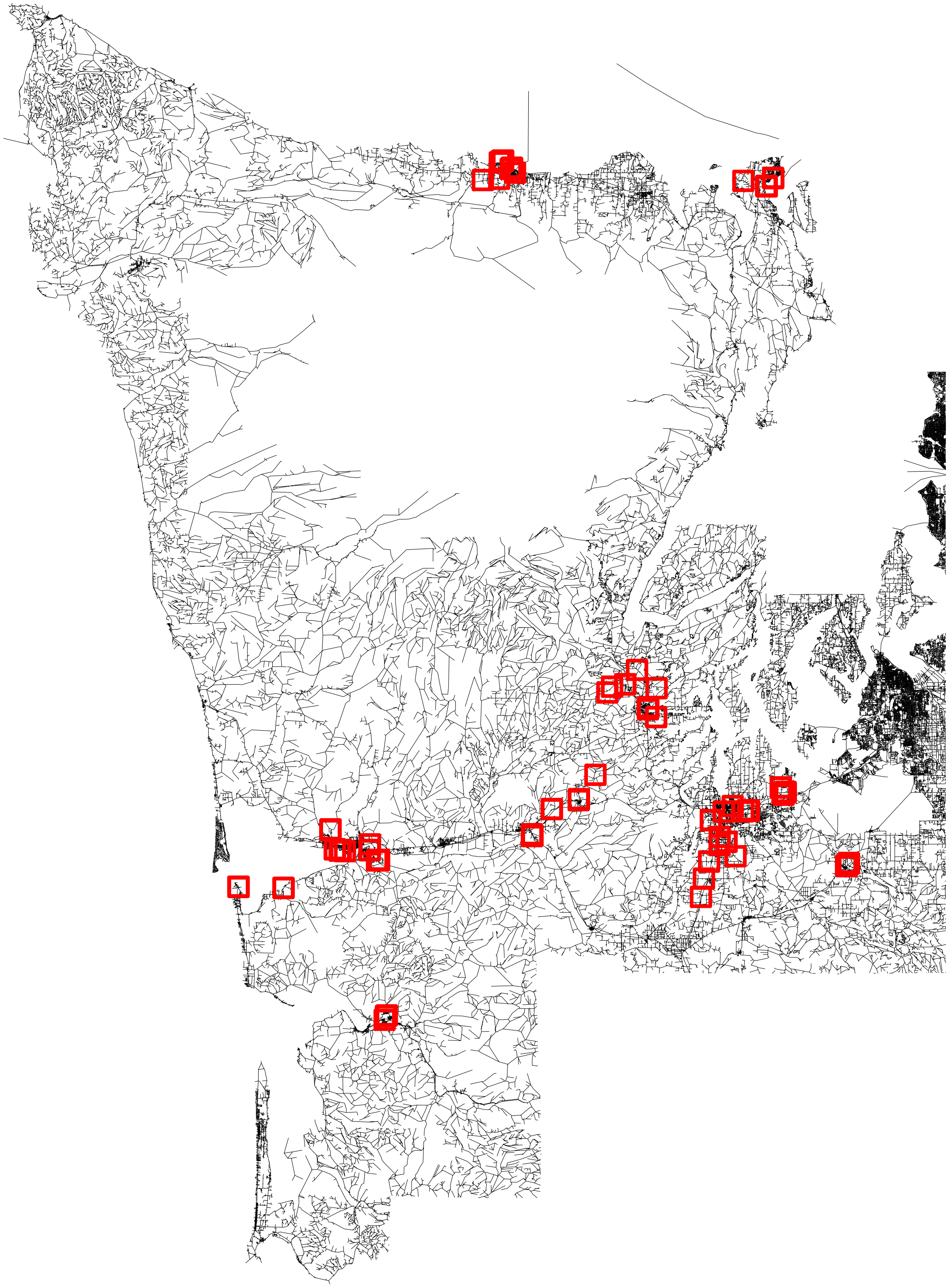
This section summarizes results of the emissions inventory development.

3.2.1 Commercial Sources (Point Sources)

The emission inventory database contains 53 commercial facilities having 107 release points. These release points are sometimes referred to as point sources. This terminology can be a bit confusing because the term “point source” also refers to the specific parameters of the release. According to the terminology used in dispersion analysis, release points can be point sources, area sources, volume sources or open pit sources. In this context, “point source” means a conventional stack, as opposed to an area or volume source. In this report we use the term “commercial source” to refer to release points associated with commercial facilities, which may be of any of the four types mentioned above.

The following figure shows the locations of the 107 release point in the Olympic region.

Figure 3-5. Point source locations. This map shows the locations of all of the release points for commercial sources included in this project. Some facilities may have more than one release point.



The following table lists the total annual emissions for all point sources included in the Olympic region study areas.

Table 3-2. Total Annual Emissions for all point sources included in the Olympic Region study areas. The values are obtained by adding together the annual emission rates for all facilities.

CAS	*Chemical*	*Emissions (lbs/year)*
75343	1,1-Dichloroethane	49
95636	1,2,4-Trimethylbenzene	69
75070	Acetaldehyde	20321
107028	Acrolein	17739
107131	Acrylonitrile	71
7664417	Ammonia	44107
7440382	Arsenic	114
71432	Benzene	20474
50328	Benzo[a]pyrene	10
7440417	Beryllium	7
75274	Bromodichloromethane	109
7440439	Cadmium	26
13765190	Calcium chromate	1
630080	Carbon monoxide	10289800
56235	Carbon tetrachloride	130
7782505	Chlorine	3939
10049044	Chlorine dioxide	3275
7440473	Chromium	2
18540299	Chromium, hexavalent (& compounds)	69
112345	Diethylene glycol monobutyl ether	996
100414	Ethyl benzene	2367
111762	Ethylene glycol monobutyl ether	116856
111159	Ethylene glycol monoethyl ether acetate	46
2807309	Ethylene glycol monopropyl ether	664
50000	Formaldehyde	76361
110543	Hexane	121
7647010	Hydrochloric acid	334845
7664393	Hydrogen fluoride	124
7783064	Hydrogen sulfide	260
67630	Isopropyl alcohol	54202
7439921	Lead	260
7439965	Manganese	4213
7439976	Mercury	29
67561	Methanol	259208
74873	Methyl chloride {Chloromethane}	6
78933	Methyl ethyl ketone {2-Butanone}	23706
108101	Methyl isobutyl ketone {Hexone}	1749
80626	Methyl methacrylate	1466
75092	Methylene chloride {Dichloromethane}	2279

CAS	Chemical	Emissions (lbs/year)
101688	Methylene diphenyl diisocyanate	1
121697	N,N-Dimethylaniline	870
91203	Naphthalene	145
71363	n-Butyl alcohol	13
10102440	NITROGEN DIOXIDE	4774000
11101	Particulate Matter	2014800
85101	Particulate Matter 10 Microns or Less (PM10)	1846000
88101	Particulate Matter 2.5 Microns or Less	1084600
127184	Perchloroethylene {Tetrachloroethene}	132
108952	Phenol	22058
107982	Propylene glycol monomethyl ether	28
108656	Propylene glycol monomethyl ether acetate	239
106514	Quinone	179
7440224	Silver	640
100425	Styrene	429650
7446095	SULFUR DIOXIDE	3185200
7664939	Sulfuric acid	16159
108883	Toluene	21374
584849	Toluene-2,4-diisocyanate	64
91087	Toluene-2,6-diisocyanate	260
75014	Vinyl chloride	150
1330207	XYLENES (mixed xylenes)	11719
7440666	Zinc	158

3.2.2 Roadway Sources

Section 5.4 (*Health Risk Assessment Results by Area*) contains figures showing the locations of all modeled roadway sources.

The following table lists the annual emissions by chemical from diesel and gasoline on-road sources for the counties in the study areas. These data were obtained from the Washington Department of Ecology.

Table 3-3. Diesel vehicle emissions for ORCAA region.

CAS	*Chemical*	*Emissions (tons/year)*
67562394	1,2,3,4,6,7,8-HEPTACHLORODIBENZOFURAN	1.826E-07
35822469	1,2,3,4,6,7,8-HEPTACHLORODIBENZO-P-DIOXIN	6.581E-07
55673897	1,2,3,4,7,8,9-HEPTACHLORODIBENZOFURAN	2.076E-08
70648269	1,2,3,4,7,8-HEXACHLORODIBENZOFURAN	8.831E-08
39227286	1,2,3,4,7,8-HEXACHLORODIBENZO-P-DIOXIN	2.789E-08
57117449	1,2,3,6,7,8-HEXACHLORODIBENZOFURAN	4.021E-08
57653857	1,2,3,6,7,8-HEXACHLORODIBENZO-P-DIOXIN	5.477E-08
72918219	1,2,3,7,8,9-HEXACHLORODIBENZOFURAN	2.339E-08
19408743	1,2,3,7,8,9-HEXACHLORODIBENZO-P-DIOXIN	1.006E-07
57117416	1,2,3,7,8-PENTACHLORODIBENZOFURAN	2.361E-08
40321764	1,2,3,7,8-PENTACHLORODIBENZO-P-DIOXIN	1.983E-08
106990	1,3-BUTADIENE	2.144E+00
540841	2,2,4-TRIMETHYLPENTANE	2.163E-01
60851345	2,3,4,6,7,8-HEXACHLORODIBENZOFURAN	5.817E-08
57117314	2,3,4,7,8-PENTACHLORODIBENZOFURAN	5.222E-08
51207319	2,3,7,8-TETRACHLORODIBENZOFURAN	5.902E-08
1746016	2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	2.344E-08
83329	ACENAPHTHENE	4.417E-03
208968	ACENAPHTHYLENE	1.085E-02
75070	ACETALDEHYDE	9.450E+00
107028	ACROLEIN	1.193E+00
NH3	AMMONIA	1.115E+01
120127	ANTHRACENE	7.051E-03
56553	BENZ[A]ANTHRACENE	6.908E-03
71432	BENZENE	3.792E+00
50328	BENZO[A]PYRENE	2.384E-03
205992	BENZO[B]FLUORANTHENE	2.213E-03
191242	BENZO[G,H,I,]PERYLENE	1.760E-03
207089	BENZO[K]FLUORANTHENE	2.213E-03
CO	CARBON MONOXIDE	1.489E+03
18540299	CHROMIUM +6	2.240E-04

CAS	*Chemical*	*Emissions (tons/year)*
16065831	CHROMIUM III	3.360E-04
218019	CHRYSENE	1.443E-03
53703	DIBENZO[A,H]ANTHRACENE	8.580E-06
100414	ETHYL BENZENE	6.554E-01
206440	FLUORANTHENE	6.255E-03
86737	FLUORENE	1.001E-02
50000	FORMALDEHYDE	2.578E+01
110543	HEXANE	1.802E+00
193395	INDENO[1,2,3-C,D]PYRENE	2.699E-04
198	MANGANESE & COMPOUNDS	3.494E-04
91203	NAPHTHALENE	2.515E-01
226	NICKEL & COMPOUNDS	1.121E-03
NOX	NITROGEN OXIDES	6.048E+03
39001020	OCTACHLORODIBENZOFURAN	2.085E-07
3268879	OCTACHLORODIBENZO-P-DIOXIN	3.031E-06
85018	PHENANTHRENE	1.444E-02
PM10-PRI	PRIMARY PM10 (INCLUDES FILTERABLES + CONDENSIBLES)	2.025E+02
PM25-PRI	PRIMARY PM2.5 (INCLUDES FILTERABLES + CONDENSIBLES	1.769E+02
123386	PROPIONALDEHYDE	2.278E+00
129000	PYRENE	9.830E-03
100425	STYRENE	6.881E-01
SO2	SULFUR DIOXIDE	1.111E+02
108883	TOLUENE	1.049E+00
VOC	VOLATILE ORGANIC COMPOUNDS	3.277E+02
1330207	XYLENES (MIXTURE OF O, M, AND P ISOMERS)	1.573E+00

Table 3-4. Gasoline vehicle emissions the ORCAA region.

CAS	*Chemical*	*Emissions (tons/year)*
67562394	1,2,3,4,6,7,8-HEPTACHLORODIBENZOFURAN	5.012E-08
35822469	1,2,3,4,6,7,8-HEPTACHLORODIBENZO-P-DIOXIN	2.464E-08
55673897	1,2,3,4,7,8,9-HEPTACHLORODIBENZOFURAN	1.603E-09
70648269	1,2,3,4,7,8-HEXACHLORODIBENZOFURAN	4.515E-09
39227286	1,2,3,4,7,8-HEXACHLORODIBENZO-P-DIOXIN	1.603E-09
57117449	1,2,3,6,7,8-HEXACHLORODIBENZOFURAN	4.805E-09
57653857	1,2,3,6,7,8-HEXACHLORODIBENZO-P-DIOXIN	3.280E-09
72918219	1,2,3,7,8,9-HEXACHLORODIBENZOFURAN	1.313E-09
19408743	1,2,3,7,8,9-HEXACHLORODIBENZO-P-DIOXIN	2.042E-09
57117416	1,2,3,7,8-PENTACHLORODIBENZOFURAN	5.467E-09
40321764	1,2,3,7,8-PENTACHLORODIBENZO-P-DIOXIN	1.533E-09
106990	1,3-BUTADIENE	5.129E+01
540841	2,2,4-TRIMETHYLPENTANE	4.219E+02
60851345	2,3,4,6,7,8-HEXACHLORODIBENZOFURAN	5.633E-09
57117314	2,3,4,7,8-PENTACHLORODIBENZOFURAN	4.009E-09

CAS	*Chemical*	*Emissions (tons/year)*
51207319	2,3,7,8-TETRACHLORODIBENZOFURAN	1.143E-08
1746016	2,3,7,8-TETRACHLORODIBENZO-P-DIOXIN	3.425E-09
83329	ACENAPHTHENE	4.381E-02
208968	ACENAPHTHYLENE	2.467E-01
75070	ACETALDEHYDE	5.227E+01
107028	ACROLEIN	6.411E+00
NH3	AMMONIA	3.814E+02
120127	ANTHRACENE	5.073E-02
56553	BENZ[A]ANTHRACENE	6.149E-03
71432	BENZENE	5.290E+02
50328	BENZO[A]PYRENE	6.149E-03
205992	BENZO[B]FLUORANTHENE	7.302E-03
191242	BENZO[G,H,I,]PERYLENE	1.537E-02
207089	BENZO[K]FLUORANTHENE	7.302E-03
CO	CARBON MONOXIDE	1.582E+05
18540299	CHROMIUM +6	8.201E-03
16065831	CHROMIUM III	1.230E-02
218019	CHRYSENE	6.149E-03
100414	ETHYL BENZENE	1.766E+02
206440	FLUORANTHENE	5.457E-02
86737	FLUORENE	9.070E-02
50000	FORMALDEHYDE	1.397E+02
110543	HEXANE	1.429E+02
193395	INDENO[1,2,3-C,D]PYRENE	4.612E-03
198	MANGANESE & COMPOUNDS	6.876E-03
1634044	METHYL TERT-BUTYL ETHER	2.175E+00
91203	NAPHTHALENE	6.630E+00
226	NICKEL & COMPOUNDS	1.491E-02
NOX	NITROGEN OXIDES	9.540E+03
39001020	OCTACHLORODIBENZOFURAN	5.675E-08
3268879	OCTACHLORODIBENZO-P-DIOXIN	1.947E-07
85018	PHENANTHRENE	1.522E-01
PM10-PRI	PRIMARY PM10 (INCLUDES FILTERABLES + CONDENSIBLES)	1.467E+02
PM25-PRI	PRIMARY PM2.5 (INCLUDES FILTERABLES + CONDENSIBLES	8.514E+01
123386	PROPIONALDEHYDE	6.270E+00
129000	PYRENE	7.457E-02
100425	STYRENE	3.553E+01
SO2	SULFUR DIOXIDE	3.274E+02
108883	TOLUENE	1.210E+03
VOC	VOLATILE ORGANIC COMPOUNDS	1.185E+04
1330207	XYLENES (MIXTURE OF O, M, AND P ISOMERS)	6.788E+02

3.2.3 Wood Stove Sources

Section 5.4 (*Health Risk Assessment Results by Area*) contains figures showing the locations of all modeled wood stove sources.

The following tables lists the annual emissions by chemical wood stove sources for the counties in the study areas. These data were obtained from the Washington Department of Ecology.

Table 3-5. Total wood stove emissions by chemical for all six counties in Olympic region.

CAS	*Chemical*	*Emissions (tons/year)*
2422799	12-METHYLBENZ(A)ANTHRACENE	0.07
832699	1-METHYLPHENANTHRENE	1.06
56495	3-METHYLCHOLANTHRENE	0.11
57976	7,12-DIMETHYLBENZ[A]ANTHRACENE	0.14
779022	9-METHYLBENZ(A)ANTHRACENE	0.14
83329	ACENAPHTHENE	0.78
208968	ACENAPHTHYLENE	12.35
120127	ANTHRACENE	1.00
56553	BENZ[A]ANTHRACENE	1.48
71432	BENZENE	148.62
203123	Benzo(g,h,i)Fluoranthene	0.60
50328	BENZO[A]PYRENE	0.38
205992	BENZO[B]FLUORANTHENE	0.44
192972	BENZO[E]PYRENE	0.71
191242	BENZO[G,H,I,]PERYLENE	0.59
207089	BENZO[K]FLUORANTHENE	0.15
92524	BIPHENYL	0.78
7440439	CADMIUM	0.00
CO	CARBON MONOXIDE	25026.46
7440473	CHROMIUM	0.00
218019	CHRYSENE	0.95
53703	DIBENZO[A,H]ANTHRACENE	0.11
206440	FLUORANTHENE	1.35
86737	FLUORENE	1.69
193395	INDENO[1,2,3-C,D]PYRENE	0.43
7439965	MANGANESE	0.01
78933	METHYL ETHYL KETONE	16.67
91203	NAPHTHALENE	20.22
7440020	NICKEL	0.00
NOX	NITROGEN OXIDES	414.95
95476	O-XYLENE	16.68
198550	PERYLENE	0.07
85018	PHENANTHRENE	6.84
108952	PHENOL	0.04

CAS	*Chemical*	*Emissions (tons/year)*
246	POLYCYCLIC ORGANIC MATTER	0.06
PM10-PRI	PRIMARY PM10 (INCLUDES FILTERABLES + CONDENSIBLES)	3344.48
PM25-PRI	PRIMARY PM2.5 (INCLUDES FILTERABLES + CONDENSIBLES	3158.44
129000	PYRENE	1.52
SO2	SULFUR DIOXIDE	51.25
108883	TOLUENE	54.87
VOC	VOLATILE ORGANIC COMPOUNDS	11124.43

4 Air Dispersion Modeling

Air dispersion modeling is necessary to obtain long-term ground level air concentrations, which are used for health risk assessment calculations. This section describes the methods used to develop modeling inputs and complete the modeling.

4.1 Dispersion Modeling Approach

4.1.1 HARP Dispersion Module and Batch Processing

Air dispersion modeling was completed using the HARP Regional Modeler. The Regional Modeler is a version of the Hotspots Analysis and Reporting Program that includes the capability to model large numbers of sources over a wide area. The modeling process consists of four steps as illustrated in Figure 5-1 below.

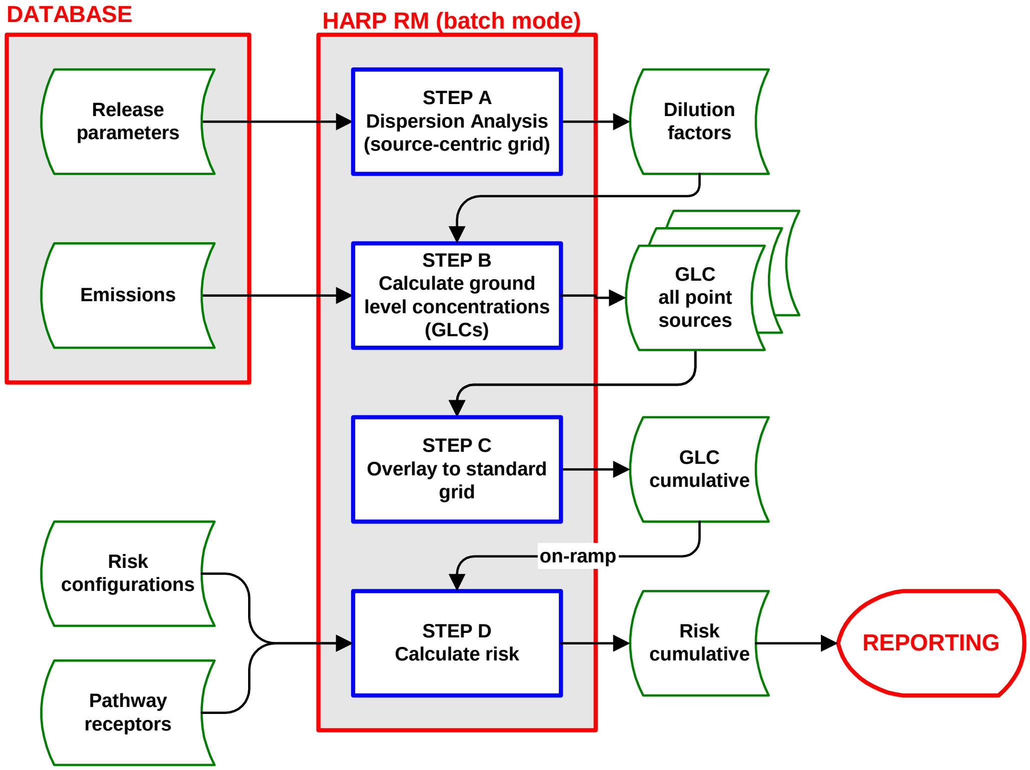
Step A : **ISCST3 Model Run for Dilution Factors.** The ISCST3 dispersion model is set up automatically by the HARP program using release parameters that are extracted from the emission inventory database. The model is run and the dilution factors are saved to a file. Separate dispersion modeling runs are made for each of the sources, including point sources, roadway sources and wood burning stove sources.

Step B: **Emission Rate Extraction**. The emission rates are extracted from the emission inventory database and multiplied by the dilution factors to get ground level concentrations (GLCs). The GLCs are stored in a file.

Step C: **Overlay Grid Creation.** GLC files from all the sources are overlaid and summed onto a common grid for risk analysis. The overlay grid spans the study area.

Step D: **Risk Calculation.** Risk is calculated for all of the points on the overlay grid following the OEHHA guidelines.

Figure 4-1. HARP batch modeling process.



4.1.2 Source and Receptors

The database of industrial point sources contains 107 release points representing 53 different facilities. Each of these was run through the dispersion analysis twice, once on a fine grid (100 meter spacing) measuring 6 km square, and a second time on a coarse grid (500 meter spacing) measuring 20 km square.

Freeways, arteries and collectors were modeled as discrete area sources. Each of these was modeled in a single ISCST3 run. The receptor grid for each of these roadway sources extended 800 meters in the axial and transverse directions from the roadway. The chemicals and emission rates for each of the roadway sources were developed from data provided by the Department of Ecology. The details of the methodology for computing emission rates is described in the Section 3 of this report.

Local roads were modeled as area sources, each being a 1 km square. The details of the methodology for developing the emission inventory for local road sources are described in Section 3. For each of these local road sources, a single ISCST3 run was made using a receptor grid that extended out to 800 meters beyond the source in all directions.

Finally, an ISCST3 run was made for each of the wood stove sources. Each of these sources was a square area source centered on a census block group centroid. The chemicals and emissions for each of these area sources were developed from wood stove emissions data obtained from the U.S. Census Bureau, as described in the Section 3.1.3.

The risk analysis was performed on regional grids centered around each of the 10 study areas. The data from the ISCST3 runs was been interpolated onto these grids and summed to obtain concentrations of all of the emitted chemicals from all sources on the common grids. Five such overlays were created for each of the 10 study areas. In Section 5.4 of this report, risk reports and maps are provided for each of these groups:

1. **On-road diesel**. All freeway, artery, collector and local road diesel sources.
2. **On-road gasoline**. All freeway, artery, collector and local road gasoline sources.
3. **Wood stove sources.**
4. **Industrial sources.**
5. **All sources** (i.e. the total of the other four groups)

Table 4-1 summarizes the air dispersion model runs.

Table 4-1. Summary of ISCST3 dispersion runs.

Source Type	***Number of Release Points***	***Number of ISCST3 runs***
Point sources	107	214
Freeways, arteries and collectors	3402	3402
Local roads	2950	2950
Wood stoves	213	213
Total	6672	6779

4.1.3 Meteorological Data

Several sources of surface wind data meteorology data were investigated. These included the following:

- EPA SCRAMM website
- NCDC, TD3280 format
- NCDC, SAMSON/HUSWO
- WRCC NOAA/NWS Cooperative Observer Network
- NCDC, ISH data

In most cases, the data had some deficiency that made it unusable, such as and excessive number of missing data points or insufficient duration. Ultimately it was decided to use the NCDC data in the TD3280 format. This data is not directly compatible with the ISCST3 program, so a conversion program was written. The TD3280 format was first converted into a format acceptable by the PCRAMMET program. Then PCRAMMET was run to produce meteorology data in a format that can be input directly to ISCST3.

Data of acceptable quality and duration was available for only three areas: Hoquiam, Olympia and Port Angeles. For other study areas the surface wind meteorology from the closest available location was used. The table below lists the meteorology data that was used for each of the 10 study areas.

PCRAMMET also requires mixing height data as input. The only mixing height data that is available for western Washington is for Quillayute. Therefore the Quillayute data was used for all study areas.

For point sources the dispersion simulation was run for three years, from January 1984 through January 1987. For the roadway and wood stove sources the simulation was run for one year, from January 1984 through January 1985. Because the roadway and wood stove sources are ground level area sources, which disperse for a relatively short distance, it was determined by experimentation that running a simulation longer than one year made negligible difference in the results.

Table 4-2. Meteorology data used for each of the study areas.

Study Area	***Surface Wind Meteorology***
Grays Harbor	Hoquiam
Aberdeen	Hoquiam
Raymond	Hoquiam
Elma	Olympia
McCleary	Olympia
Shelton	Olympia
Olympia	Olympia
Yelm	Olympia
Port Angeles	Port Angeles
Port Townsend	Port Angeles

The figures on the following pages show the wind roses for Hoquiam, Olympia and Port Angeles.

Figure 4-2. Hoquiam wind rose.

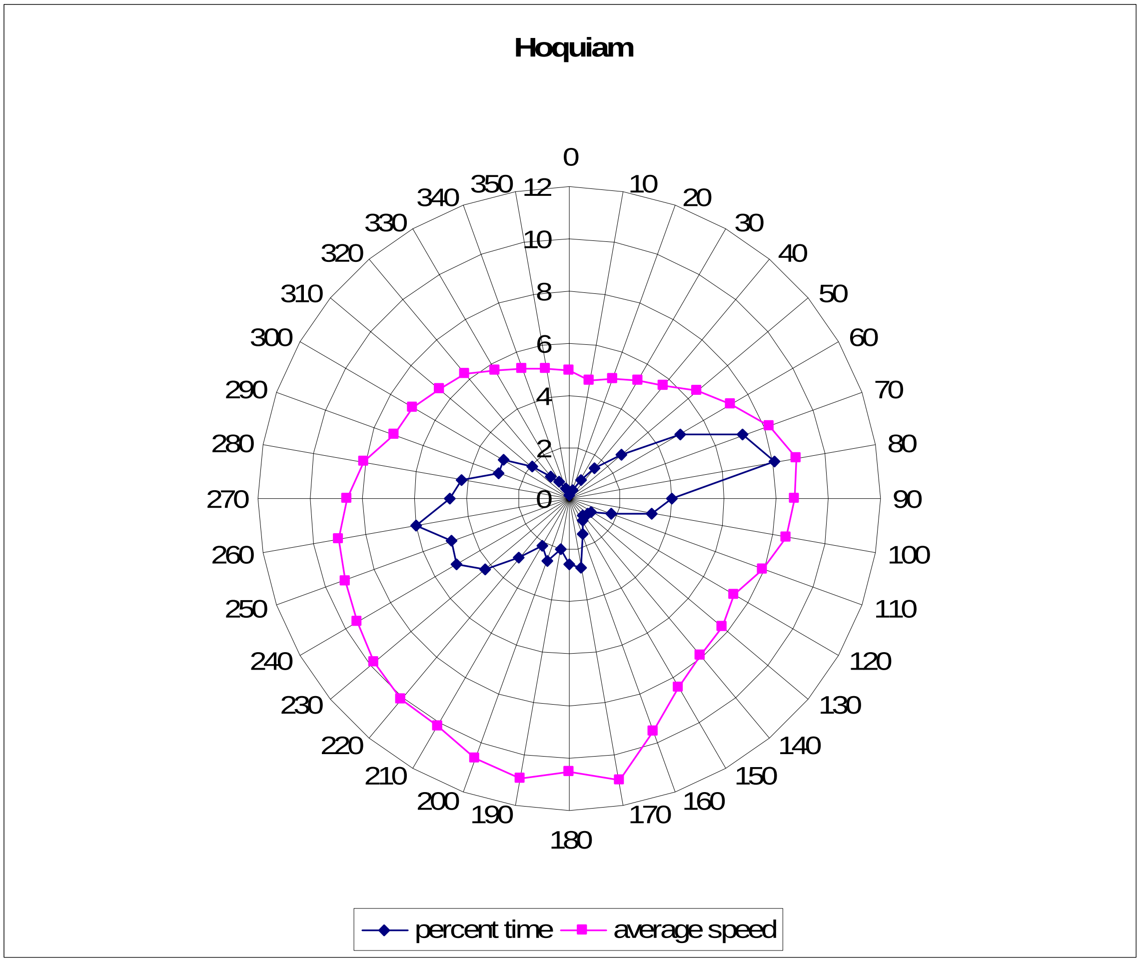


Figure 4-3. Olympia wind rose.

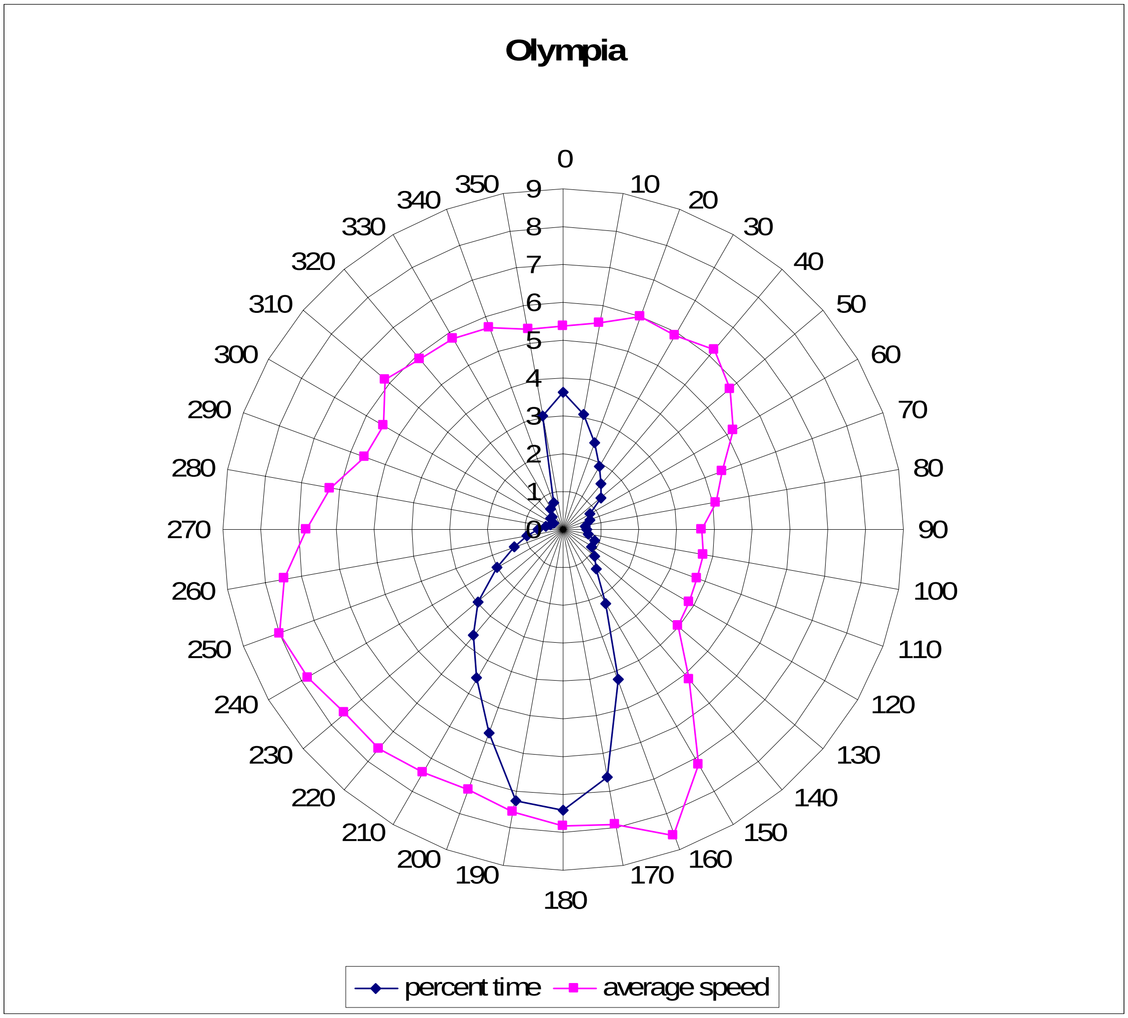
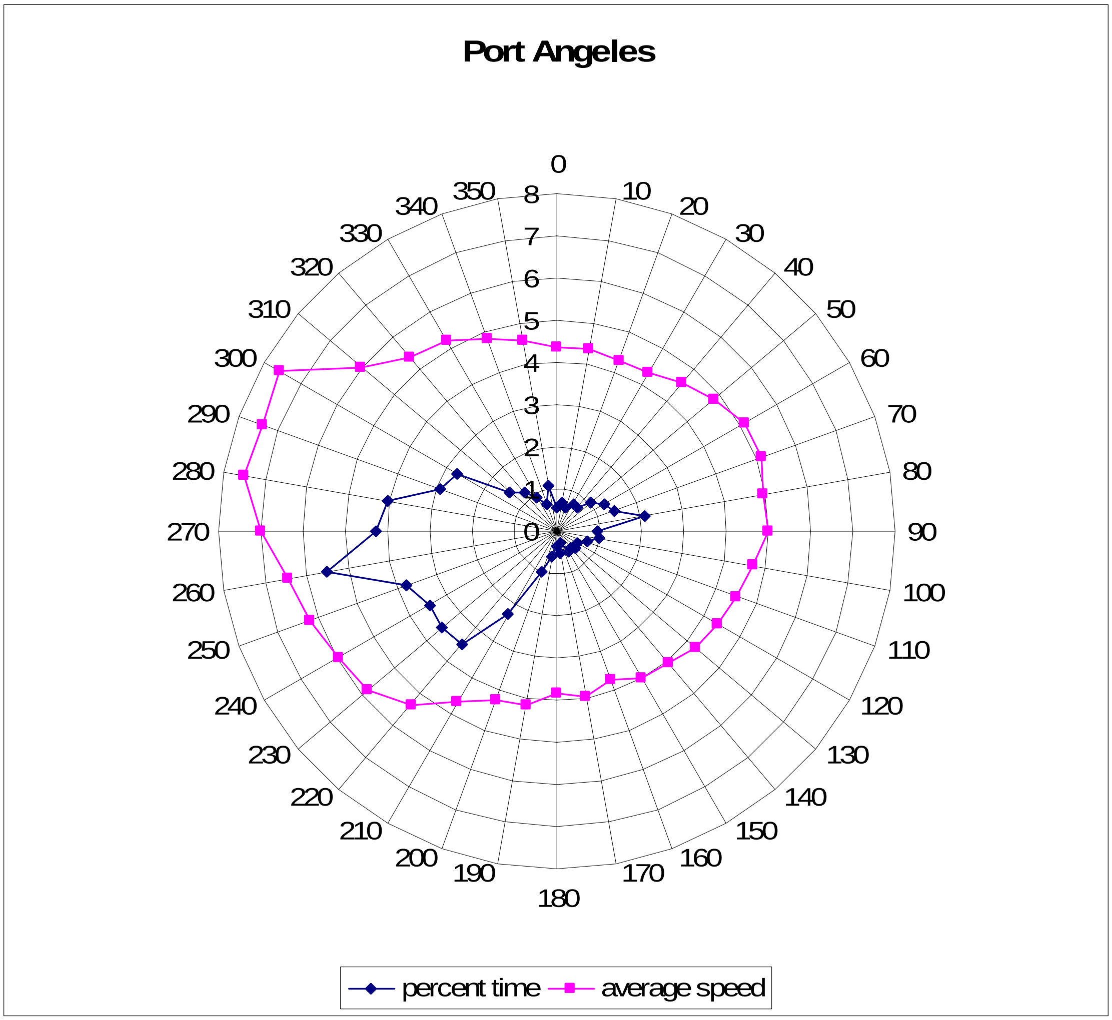


Figure 4-4. Port Angeles wind rose.

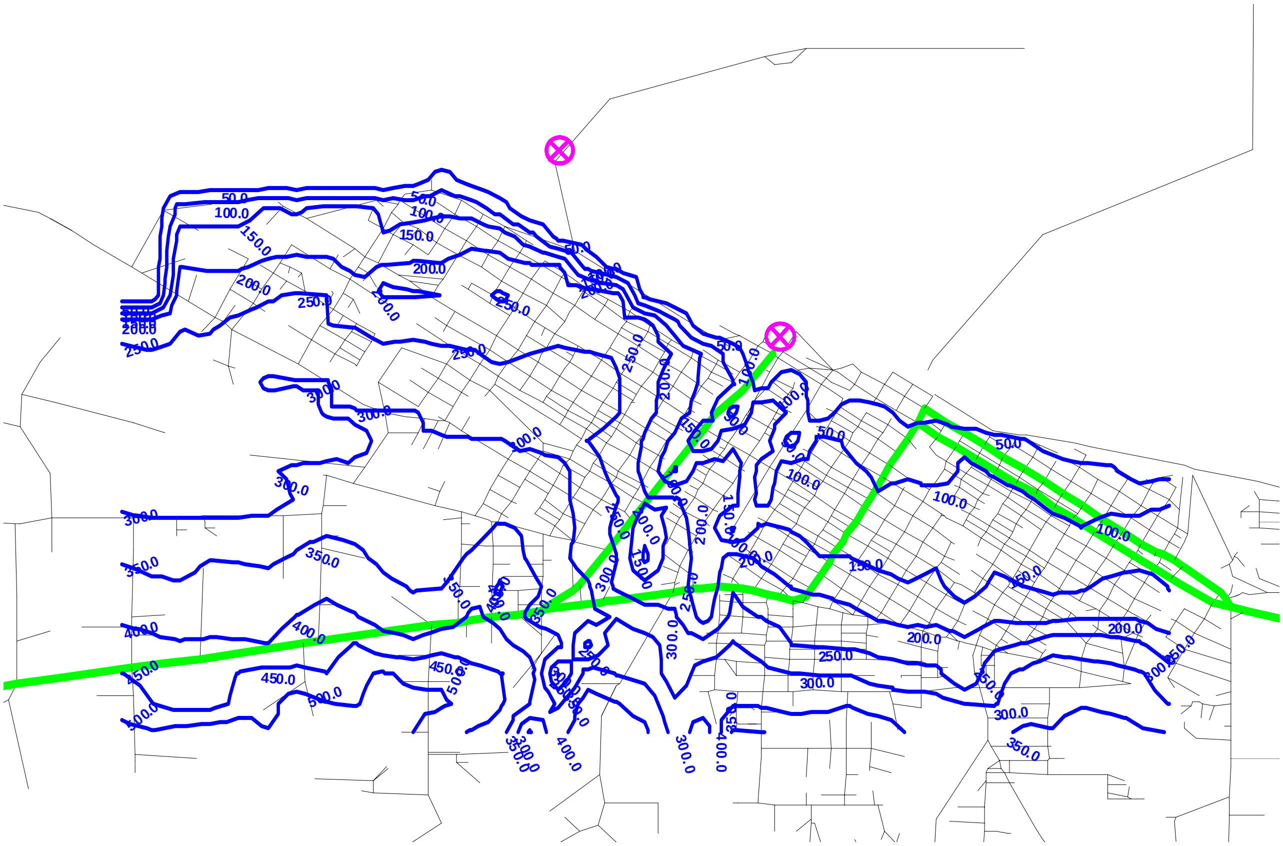


4.1.4 Topography and DEM Processing

The HARP program automatically looks up the elevations for all receptors on the receptor grid when it sets up each run. For area sources, terrain elevations do not make any difference. For point and volume sources (in the sense of ISCST3, i.e. smoke stacks) the elevation of the terrain affects the shape and extent of the plume.

The following figure shows a typical topographic map created by HARP for the Port Angeles area. The elevations come from Digital Elevation Model (DEM) files obtained from USGS (U.S. Geographical Service).

Figure 4-5. Elevation Contours for the Port Angeles.



4.1.5 Urban / Rural Classification

The land type in the Olympic Region must be classified as either rural or urban so that appropriate dispersion parameters can be used with ISCST3. The *Guideline on Air Quality Models* [4] identifies two land use classification procedures; the land-use procedure and the population density procedure. Because the affected areas are all small urban areas, the Urban dispersion coefficients were selected for all study areas.

4.1.6 Model Options Used for Dispersion Analysis

For all ISCST3 dispersion model runs the regulatory default options were used by specifying the DFAULT keyword on input. The regulatory default options are identified in the Guideline on Air Quality Models [4], and include the following:

- Use stack-tip downwash
- Use buoyancy-induced dispersion
- Do not use gradual plume rise

- Use the calms processing routines
- Use upper-bound concentration estimates for sources
- influenced by building downwash from super-squat buildings
- Use default wind speed profile exponents
- Use default vertical potential temperature gradients

The emission inventory database does not contain any building geometry at this time. Therefore building downwash was not included in the analysis. Building downwash can affect the shape of the plume, typically by moving the point of maximum concentrations closer to the source. When there are many sources and buildings, the aggregate affect cannot be stated generally. On a regional scale we do not expect that the omission of building downwash will have a significant effect on the overall results, but for more detailed resolution of local effects close to specific sources building downwash should be considered.

4.2 Limitations and Assumptions

This section describes some of the assumptions and limitations of the dispersion analysis that was performed.

There are many approximations inherent in dispersion modeling. The model uses representative meteorology from a particular span of time, which may not accurately represent any particular time in the future. The Gaussian plume model is a rough approximation, which is used because of its simplicity and because it has proven to be representative of reality in a general sense. The actual flow patterns at any given time may vary widely from this model approximation in particular instances.

Urban dispersion modeling options were used for all runs. This was done for consistency and simplicity, and because all of the areas of interest are small to medium sized urban areas. The outlying regions of each study area are not necessary urban however, but may be better characterized as forested. Some further study may be warranted to determine the affect of using the urban approximation for all regions.

All of this analysis was done using the Industrial Source Complex (ISCST3) computer program, which was developed by the USEPA, and can be downloaded from the SCRAM web site. The accuracy of the dispersion results presented in this report is therefore subject to the approximations and limitations of the ISCST3 model.

Dispersion modeling requires that certain physical parameters be provided for all modeled release points. For stacks the required physical parameters are stack height, stack diameter, flow rate, temperature of released gasoline and elevation of the base of the stack. For releases that are not stacks, the model requires information on the geometry of the area or volume source. In order to compute the ground level concentrations, the emission rates of all chemicals are also required.

The dispersion model for point sources was built using the data that was available in the emission inventory database provided by ORCAA. Populating the emission inventory database required some assumptions about some of the individual sources where limited information was available.

For roadway sources, the models were built following the procedures and assumptions described in Section 4.1 . These assumptions are summarized below:

- All roadways were modeled as area sources.
- All roadway sources are assumed to be released at ground level.
- The initial vertical dispersion (the parameter SZINIT in the ISCST3 input) was assumed to be 10 feet.
- For freeways, arteries and collectors each link of the roadway was modeled as a discrete area source having a width of 16 meters. The length of each link was assigned such that no link has an aspect ratio exceeding 100:1. The emissions for each of these links was assigned proportional to the length of the link (see Section 3.1.2).
- Local roads were modeled as area sources, each being 1 km square, and having emission rates proportional to the miles of local roads within that square.

For wood stove sources, a rough distribution of wood stove emissions was developed based on available data from the census bureau. This data describes the number of households that use wood as a heating fuel within each census block group. The details are described in Section 3.2.3. Each of the census block groups was modeled as an area source with a release height of 20 feet. The shape of each of the census block groups was not factored into the analysis. Each was modeled as a rectangular source having the correct area. This was deemed to give approximately the correct spatial distribution, but cannot provide fine scale spatial resolution. Therefore the reader should not infer too much from the locations of the hot spots associated with wood stove emissions, other than the general area.

Building downwash was not included in the model, since data was not available and this level of detail was out of the scope of the project. The dispersion flow patterns may be significantly affected by building downwash for specific sources. This will particularly affect the concentrations of pollutants in close proximity to the release points. Therefore, the concentrations and associated risk near to, and resulting from, individual facilities might be significantly different if these details are included.

The results of the dispersion model were computed at grid points having a spacing of 200 meters across the study area. Therefore, one should not presume that the locations of contours or points of maximum impact to have an accuracy of better than 200 meters. This also means that peak values that happen to fall in between the modeled grid points will not the captured in this analysis.

5 Health Risk Assessment

Phase 3 is the health risk assessment was completed using the HARP software following the procedures and chemical potency values provided in the OEHHA guidelines. Cancer risk and chronic non-cancer risk values were calculated for modeled receptor locations within the each of the study areas. This section describes the health risk assessment methods, and summarizes the health risk assessment results.

5.1 Health Risk Assessment Approach

5.1.1 HARP Health Risk Assessment Module – Overview of Methodology

The HARP risk assessment module is a core library that includes all of the risk analysis equations and parameters defined in the OEHHA guidelines [1]. This module integrates with the database management and dispersion modules of the HARP program.

5.1.1.1 Ground Level Concentrations

Dilution factors (X/Q values) are read from the output of the ISCST3 program. These dilution factors (in units of (micrograms/cubic meter)/(gram/second)) are multiplied by the emission rates (in units of grams/second) for each source to obtain the ground level concentrations (GLCs) of all emitted chemicals at each of the receptors. Emission rates are stored in the HARP database in units of lbs/year, and are converted to grams/second by HARP when performing the calculations. The GLCs from each of the sources are then added together to obtain the total (cumulative) GLCs from all sources at each receptor location. This is done for each of the following source groups (point source, on-road diesel, on-road gasoline, wood stove, and total of all sources). These cumulative GLCs are then stored in data files, called overlays, which can be recalled for computing risk.

The ground level concentrations are used as input to the OEHHA risk analysis equations, which are used to compute cancer, chronic non-cancer (long term) and acute (short term) health effects. In this project acute risk is not computed because short term (1 hour) emission rates are not available.

5.1.1.2 Dose

Calculation of dose is an intermediate step towards calculation of cancer and chronic non-cancer risk. Dose calculation can be quite complex, and will therefore not be described in detail. We will give a summary here and refer the reader to the OEHHA Guidelines [1] for further details. The HARP program follows the OEHHA Guidelines rigorously.

Dose is expressed in units of mg of chemical per kg of human body weight per day (mg/(kg-day)). Therefore it is really a dose rate. Expressing the dose in terms of “per body weight” eliminates the need to include body weight of individuals explicitly in the formulation.

Dose calculations can include up to 12 exposure pathways, which are defined in the OEHHA Guidelines. In this project only three of the pathways are included: inhalation, soil ingestion and dermal exposure. These are referred to as the “minimum pathways”. The remaining pathways (water ingestion, food ingestion, etc.) require detailed knowledge of the local site-specific parameters that is not available at this time. Example of site-specific parameters are the location and depth of the local drinking water source and the location of the pasture where the locally grown beef and dairy cattle graze. The California Air Resources Board has recommended that when site specific parameters are not known the three minimum pathways should be used.

Inhalation dose rate is the product of ground level concentration (micrograms per cubic meter) and inhalation rate (cubic meters per kg body weight per day). To obtain an average dose rate we multiply the result by the exposure duration (days) and divide by the averaging time (days). The exposure duration is different for adults, workers, residents and children. For adult residents the exposure duration is assumed to be 70 years (25550 days). The averaging time is always assumed to be 70 years for all individuals (25550 days), which represents a typical lifetime.

Dose from dermal exposure and soil ingestion is somewhat more complex. The reader is referred to the OEHHA Guidelines [1] for details.

Non-inhalation (oral) dose is just the sum of the doses from the non-inhalation pathways.

5.1.1.3 Cancer Risk

Cancer risk is reported as a probability. This can be interpreted as either the probability of an individual contracting cancer, or the fraction of people out of the population who are likely to contract cancer if exposed to the ambient concentration for a 70 year lifetime. This is a mathematically non-rigorous representation of risk that is generally accepted in the industry. It should not be construed to predict the actual number of cancers that will develop in a particular location over a particular period of time. Rather it should be interpreted as an approximation to the actual probability of contracting cancer, which is useful as a metric for comparing risk from one location to another, and as a benchmark for assessing the relative risk from emissions from various pollution sources.

Cancer risk may be presented as either a non-dimensional probability, or it may be scaled by a factor of a million and expressed as “chances per million”. For example, a cancer risk of 1.0E-6 is equivalent to 1 per million, and may be expressed in either form.

Cancer risk is a dimensionless quantity obtained by multiplying the inhalation dose rate (mg/(kg body weight – day)) by the inhalation cancer slope factor (1 / (mg/(kg body weight – day))) and adding the oral dose rate times the oral cancer slope factor. Inhalation and oral (non-inhalation) slope factors may be different.

Cancer slope factors were obtained from the CARB database that was developed for use with HARP and is published on the CARB web site.

5.1.1.4 Chronic Non-cancer Risk, Health Hazard Index

Chronic non-cancer risk is based on the ground level concentration for the inhalation pathway, and is based on the oral dose rate for oral pathways. For chronic risk the oral dose rate is based on an averaging time that is always equal to the exposure duration, whereas for cancer risk the averaging time is set to 70 years. For chronic risk the exposure duration and averaging time always cancel each other out of the equation.

There are 12 toxicological endpoints (commonly called organ systems) that are considered in the estimation of chronic non-cancer risk. Chronic non-cancer risk is computed separately for each of the 12 endpoints, and the overall risk is obtained by taking the maximum the 12 values. (In other words, the overall risk it is the maximum of the 12 endpoints, not the sum).

For each of the endpoints, the risk is the sum of the risks computed for each of the chemicals to which the body is exposed. The risk contribution of each chemical is called the health quotient (HQ). The oral HQ is obtained by dividing the dose rate by the oral chronic reference exposure level (REL) for the chemical, both in units of mg per kg body weight per day. Inhalation HQ is obtained by dividing the ground level concentration (GLC) by the inhalation chronic REL, both in units of micrograms per cubic meter. RELs are obtained from the CARB database. The sum of the oral and inhalation HQs across all chemicals is called the health index (HI) or health hazard index (HHI) for an endpoint. If there is only one chemical present, HQ and HHI for each endpoint are the same. The overall HHI for a receptor is the maximum of the HHI's among all of the endpoints.

Not all organ systems are affected by all chemicals. The CARB database that is used by HARP contains data fields that identify which organ systems are affected by each chemical, and only those that are affected are included in the analysis.

5.1.2 Risk Analysis Options

5.1.2.1 Pathways

The OEHHA guidelines identify 12 pathways that should be included, when appropriate, in the analysis of health effects. The term "pathway" refers to a route that the chemicals can take to reach the human receptor's organs. Possible pathways include these:

1. Inhalation
2. Dermal contact with soil
3. Soil ingestion
4. Drinking water

5. Fish ingestion
6. Beef ingestion
7. Home grown produce (vegetable) ingestion
8. Dairy product ingestion
9. Pig ingestion
10. Chicken ingestion
11. Egg ingestion
12. Ingestion of mother's milk by nursing infant

Aside from the first three pathways, all of the other pathways require some detailed information about the location and specific details of some food or water source. In many instances these pathways may be irrelevant, particularly in urban areas where residents typically do no grown produce at home and the food (e.g. beef and dairy products) may be imported from outside of the area affected by the local pollution sources.

In situations where the food and water pathways are irrelevant, or the data necessary to analyze these pathways is not available, it is common practice to include in the analysis the so-called "minimum pathways". The minimum pathways are the first three pathways listed above: inhalation, dermal and soil ingestion. Including these pathways in the analysis requires knowing the ground level concentrations only at each of the target receptors. It does not require that we know the GLC at other "pathway receptors", such as drinking water sources and pastures.

For all of the analysis described in this report, the minimum pathways were used.

5.1.2.2 Analysis Method

The term "analysis method" refers to one of several methods defined by OEHHA that can be applied when computing risk. The options are:

1. **Average Point Estimate.** For each of the intake factors, use the average value from the sampled population.
2. **High-End Point Estimate.** For each of the intake factors, use the high-end value from the sampled population. This is typically the 95 percentile value.
3. **80th Percentile Point Estimate, Inhalation Only.** Include only the inhalation pathway. Use an inhalation rate that is the 80th percentile from the sampled population.
4. **Derived (OEHHA) Method.** This is a hybrid between the average and high-end estimates. Use the high-end estimates for the two dominant pathways and the average estimate for the other 10 pathways. The dominant pathways are the two pathways that make the greatest contribution to risk when using high-end estimates of intake rates for all pathways.
5. **Derived (Adjusted) Method.** This is the same as the Derived method, except that if the inhalation pathway is dominant use the 80th percentile inhalation rate rather than the high-end estimate of inhalation rate.

For all of the analysis described in this report the Derived (OEHHA) Method is used.

5.1.2.3 Scenario

The term "scenario" refers to the exposure profile of the human receptors. The options are:

1. **70 year adult resident**. An adult who is assumed to reside at the receptor location for 70 years.
2. **30 year adult resident.** An adult who is assumed to reside at the receptor location for 30 years.
3. **9 year adult resident**. An adult who is assumed to reside at the receptor location for 9 years.
4. **9 year child resident.** A child who is assumed to reside at the receptor location for 9 years. Children have different intake rates than adults for all pathways. Therefore the designation of child vs. adult is significant.
5. **Worker**. Workers are typically assumed to be in the vicinity for 30 years, but their exposure frequency is less because they are usually only present for 5 days/week and 8 hours/day, compared to a resident who is assumed to be present 24 hours per day, seven days per week.

For all of the analysis presented in this report, receptors were assumed to be 70 year adult residents.

5.1.2.4 Site Parameters

Site parameters refer to the specific details of each of the pathways. These include, for example, the fraction of drinking water that comes from a local contaminated source, the fraction of ingested vegetables that are locally grown, etc. Because "minimum pathways" are assumed (see section 5.1.2.1) all of the site parameters are irrelevant, except for deposition rate (see the next section).

5.1.2.5 Deposition Rate

The user must specify the deposition flux velocity as an input to the analysis. This velocity is used to compute the deposition rate of chemicals on the soil and vegetables (vegetables ingested by humans as well as vegetables ingested by animals). Although we are not including food pathways in the analysis, the deposition rate nevertheless affects the concentration of pollutants in the soil, which affects the contribution to risk through the dermal and soil ingestion pathways.

The values of deposition rate recommended by OEHHA are:

- 5 cm/second for pollution from uncontrolled sources
- 2 cm/second for pollution for controlled sources

For all of the analysis described in this report, the 5 cm/second deposition rate was assumed, because we do not have data on the source controls and the higher deposition rate is a more conservative assumption (i.e. will lead to a higher risk estimate)

5.1.2.6 Health Effects

The OEHHA guidelines identify three types of health effects that should be analyzed:

- **Cancer Risk.** Carcinogenic effects resulting from long-term exposure to pollutants, based upon long-term average concentrations.
- **Chronic Non-cancer Risk**. Non-carcinogenic effects resulting from long-term exposure to pollutants, based upon long-term average concentrations.
- **Acute Risk.** Short-term health effects, typically based on maximum 1-hour concentrations. For some chemicals, OEHHA provides acute reference exposure levels that are based on 4, 6 or 7-hour exposures rather than the more typical 1-hour exposure. The HARP program therefore computes the 4, 6 and 7 hour average concentrations during the dispersion analysis and applies the correct averaging time during the risk analysis for those chemicals.

This report presents results for cancer and chronic non-cancer health effects. No acute analysis was done because of lack of availability of short term (1 hour) emission rates for commercial sources.

5.1.3 Air Toxic Chemical Characteristics

Prior to completing health risk calculations, it is important to identify whether exposure to a particular compound may result in cancer, chronic non-cancer or acute risk impacts. The HARP software has a built-in database that identifies air toxic chemicals that must be considered in health risk assessment according the procedures recommended by the California EPA. The list of chemicals is described in Tables 6.1, 6.2, 6.3, and 7.1 of the OEHHA guidelines.

For cancer risk assessment, inhalation cancer potency factors and oral slope factors are used, in units of $(mg/kg\text{-}day)^{-1}$. Chronic non-cancer risk is calculated in terms of chronic non-cancer health hazard indices (HHIs) using chronic inhalation reference exposure levels (units of $\mu g/m^3$) and oral reference exposure levels (units of mg/kg-day). The most current chemical potency factors are provided in the references and Web addresses listed in Section 1.3.

OEHHA and CARB continually review and update air toxic chemical lists. The current list released by CARB can be found on the website at www.arb.ca.gov/toxics/healthval/healthval.htm and is dated April 25, 2005. Additional information regarding air toxic identification can be found at www.oehha.org/air/hot_spots/index.html.

5.1.4 Risk Calculation Methods

The OEHHA guidelines provide extensive discussion of health risk calculation methods. The reader is referred to Chapters 5-8 of those guidelines. The OEHHA risk calculation methods are built-in to the HARP software.

5.2 Limitations and Assumptions

As stated in the OEHHA guidelines [1], "there is a great deal of uncertainty associated with the process of risk assessment. The uncertainty arises from lack of data in many areas necessitating the use of assumptions. Sources of uncertainty, which may either overestimate or underestimate risk, include: 1) extrapolation of toxicity data in animals to humans, 2) uncertainty in the estimation of emissions, 3) uncertainty in the air dispersion models, and 4) uncertainty in the exposure estimates."

A major goal of this regional health risk assessment is to provide ORCAA with information regarding sources of risk and associated impacts. The risk assessment follows standardized procedures developed by OEHHA to facilitate simplified calculation methods and consistent risk comparisons. Given the limitations and assumptions stated and used in this health risk assessment are highly conservative and likely to overstate actual risks.

Risk analysis was done using the HARP program, which was developed by Dillingham Software Engineering, Inc. for the California Air Resources Board (CARB). The HARP program has been validated and approved by CARB for use in California. HARP follows the methods described in the OEHHA guidelines (reference [1]). The accuracy of the risk analysis results presented in this report is therefore subject to the approximations and limitations of the OEHHA guidelines. The reader should refer to reference [1] for a full understanding of these limitations.

There are numerous approximations and uncertainties inherent in the OEHHA methodology. The two most important areas of uncertainty are:

- **Intake rates.** For multipathway analysis these include inhalation rate, water ingestion rate, food ingestion rates, and rates of exposure to soil through dermal and soil ingestion pathways. The HARP program uses the intake rates recommended in the OEHHA guidelines. The interested reader should refer to reference [1] for detailed information on the data used to support those recommendations.
- **Chemical toxicities**. Three volumes of reference [1] are devoted to developing the chemical toxicities for cancer, chronic non-cancer and acute health effects for numerous chemicals. HARP uses the values provided by OEHHA, which are published and periodically updated by CARB. There are a few chemicals found in the emission inventory for the Olympic region for which toxicities are not available through CARB. For these chemicals no health effects are reported in our analysis. The table below is a list of all of those chemicals.

Cancer risk is reported in terms of "chances per million". This can be interpreted as either the probability of an individual contracting cancer, or the number of people out of a population of a million who are likely to contract cancer if exposed to the ambient concentration for a 70 year lifetime. This is a mathematically non-rigorous representation of risk that is generally accepted in the industry. It should not be construed to predict the actual number of cancers that will develop in a particular location over a particular period of time. Rather it should be interpreted as an approximation to the actual probability of contracting cancer, which is useful as a metric for comparing risk from one location to another, and as a benchmark for assessing the relative risk from emissions from various pollution sources.

In many places in this report, risk is reported at the PMI (point of maximum impact). This is done in most cases without regard for whether that specific location is a residential neighborhood, an industrial area, or even an on-site location (i.e. within the property boundary of the facilities causing the risk). When considering the full impact of these reported risk values, the reader should therefore consider the location and nature of the land use at the impacted locations.

There are some chemicals in the emission inventory for which no toxicity data is available in the CARB consolidated tables. These chemicals are listed in the table below. For these chemicals health risk could not be computed and is assumed to be zero.

Table 5-1. The following is a list of pollutants for which no toxicity values are present in the California Air Resources Board Consolidated Tables. Each of these pollutants was present either in the commercial source emission inventory or in the roadway and wood stove emission inventories.

CAS	Chemical
246	Polycyclic Organic Matter ***
67641	Acetone
80568	a-Pinene
109999	Tetrahydrofuran
112072	2-Butoxy Ethyl Acetate
779022	9-Methylbenzanthracene
832699	1-Methylphenanthracene
2422799	12-Methylbenzanthracene
16065831	Chrome III

****** The CARB database does not contain health factors for Polycyclic Organic Matter (POM). POM was treated as Benzo[a]pyrene (BaP) at ORCAA's recommendation.***

5.3 Health Risk Assessment Results - Summary

5.3.1 Cancer Risk

Cancer risk results are shown in this report for point sources, diesel on-road sources, gasoline on-road sources, wood stoves, and all sources combined. Section 5.2 contains cancer risk results for each of the study areas.

5.3.1.1 All Sources, Cancer Risk

The following table and figures show the cancer risk at the PMI for each study area for all sources. Note that the PMI may be located directly on a major roadway, and therefore may not indicate the risk to any particular resident.

Table 5-2. Cancer risk at PMI for each study area, all sources.

Study Area	PMI Cancer Risk from all sources (per million)
Port Angeles	381
Aberdeen	495
Grays Harbor Coastal	137
Raymond	213
Elma	273
McCleary	266
Olympia	2070
Yelm	432
Shelton	515
Port Townsend	244

Figure 5-1. Cancer risk at PMI for each study area, all sources.

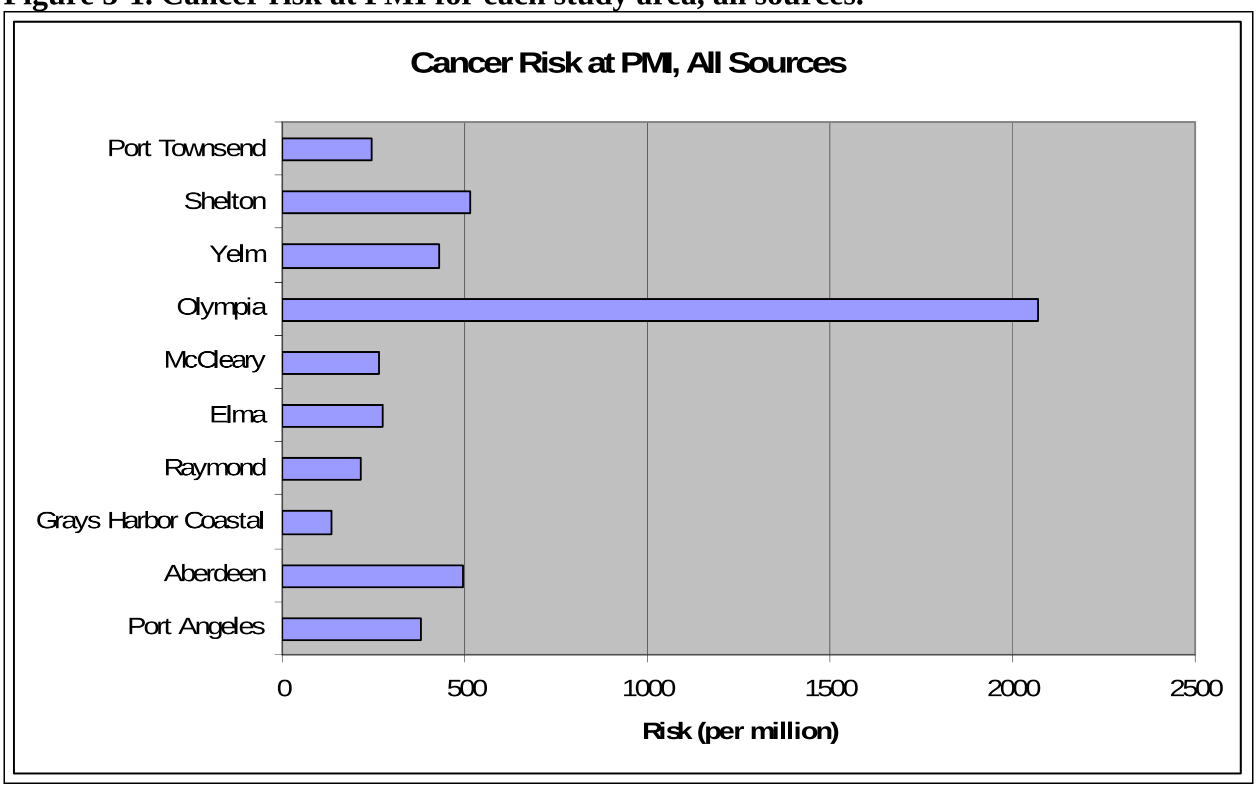
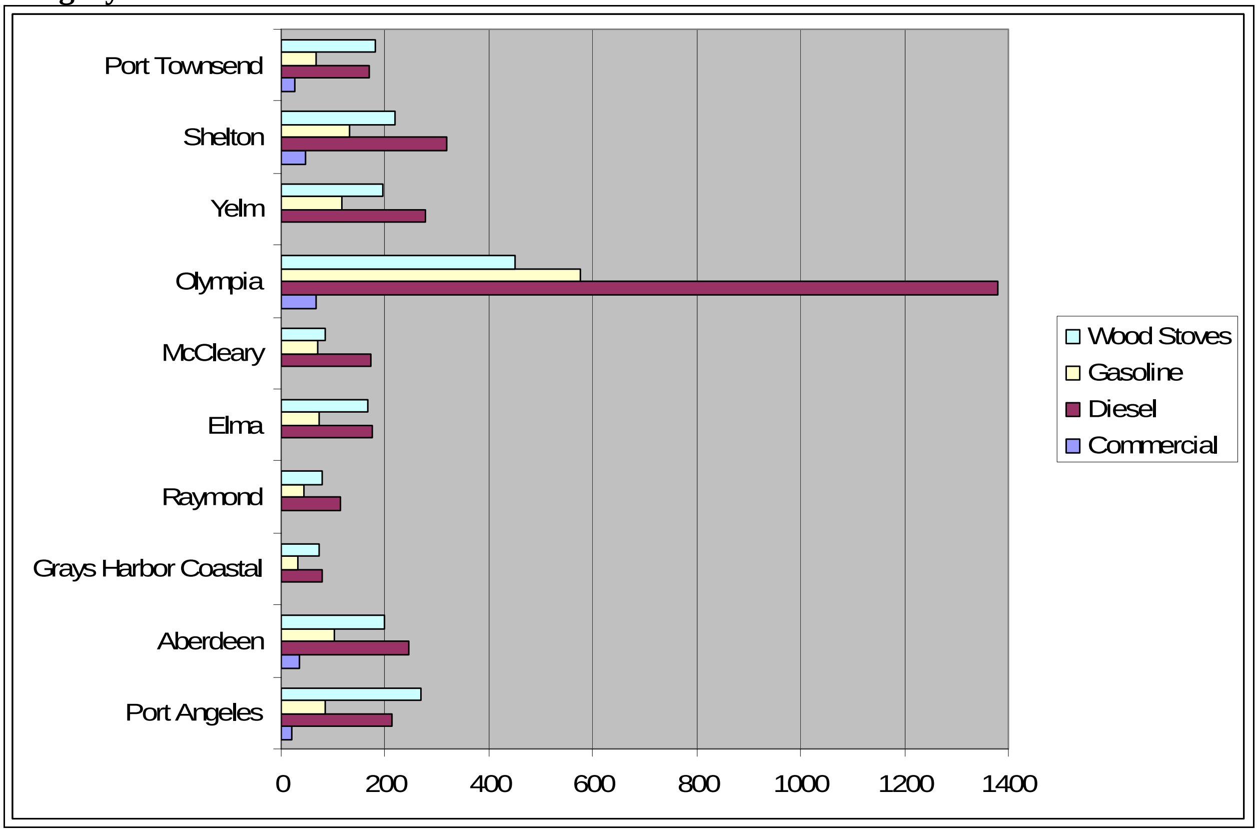


Figure 5-2. Cancer risk at PMI for each study area, all sources, broken down by source category.



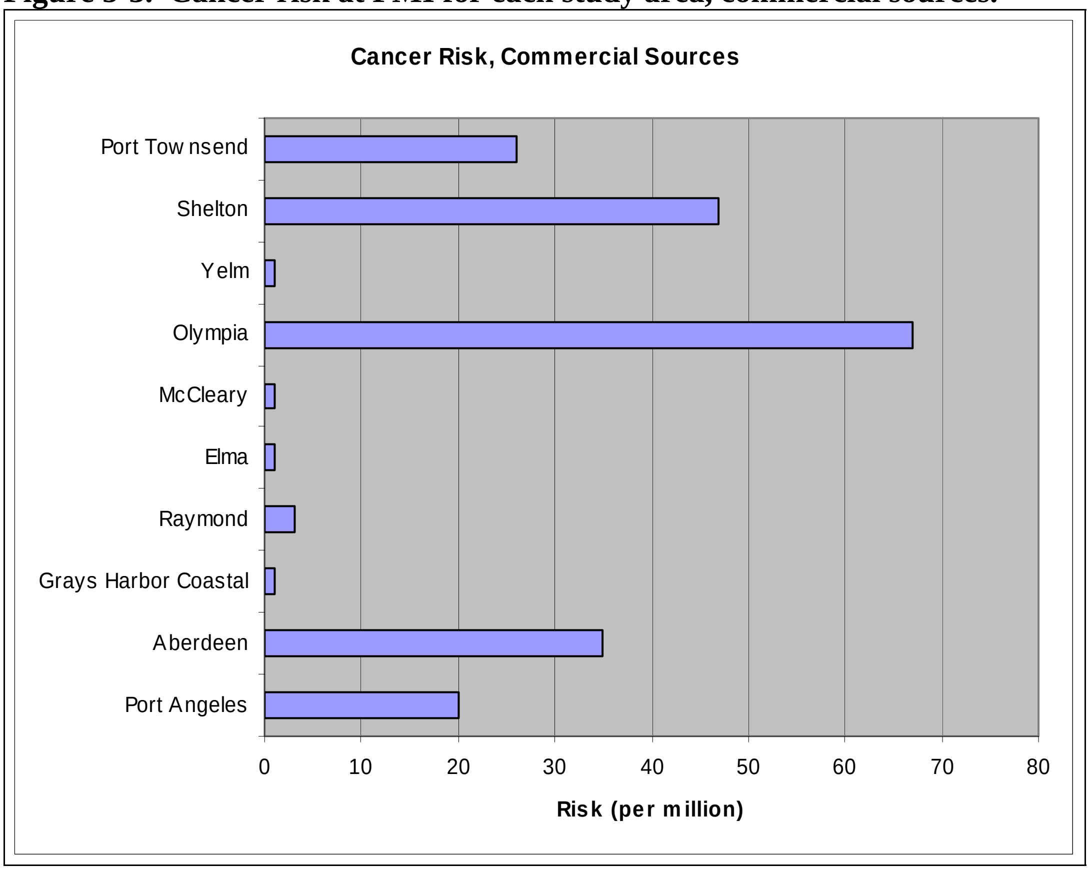
5.3.1.2 Commercial Sources, Cancer Risk

Cancer risk from commercial point sources varies from one region to another. The results for each region are summarized in the following table and figure.

Table 5-3. Cancer risk at the point of maximum impact (PMI) for each of the study areas.

Study Area	PMI Cancer Risk from commercial point sources (per million)
Port Angeles	20
Aberdeen	35
Grays Harbor Coastal	<1
Raymond	3
Elma	<1
McCleary	<1
Olympia	67
Yelm	<1
Shelton	47
Port Townsend	26

Figure 5-3. Cancer risk at PMI for each study area, commercial sources.



5.3.1.3 On-road Diesel Sources Cancer Risk

Cancer risk from diesel sources typically reaches levels of several hundred per million in close proximity to major freeways, arteries and collectors. The risk drops off quickly with distance from the road. At a distance of about 500 meters, the cancer risk is typically in the range of 10-20 per million. Because risk from multiple sources is additive, some areas that have several major roads converging at one point have computed risk values several times higher than this over a small area near the intersections of major roads.

Figure 5-4 below shows a typical section of roadway (in this case a collector), in the Port Angeles study area, illustrating the range and magnitude of the cancer risk from diesel sources.

Figure 5-4. Contours of cancer risk from diesel on-road sources for an area of Port Angeles. The maximum cancer risk in this area is 212 per million. The risk drops off to below 10 per million at a distance of about 500 meters from the roadway.

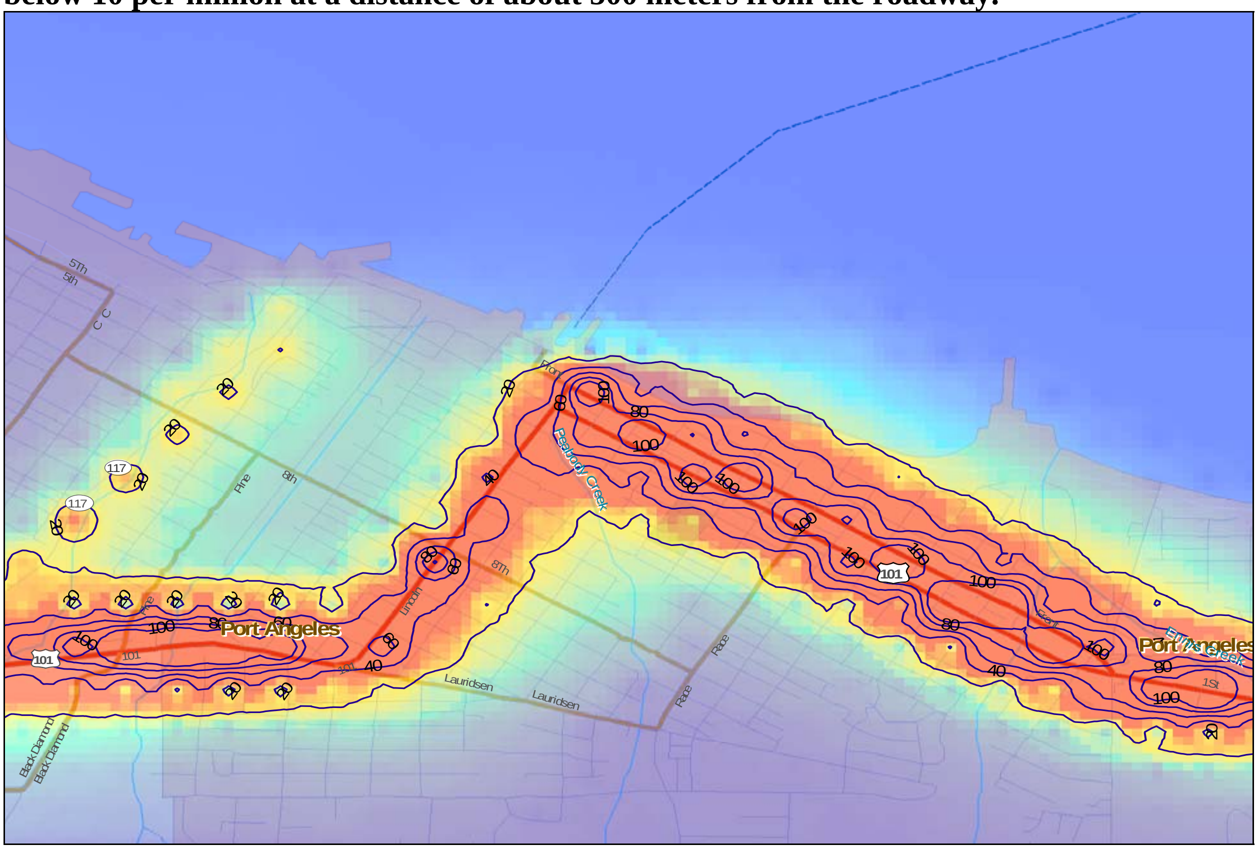


Table 5-4. Cancer risk from on-road diesel sources for each of the study areas.

Study Area	PMI cancer risk from on-road diesel sources
Port Angeles	212
Aberdeen	245
Grays Harbor Coastal	80
Raymond	113
Elma	174
McCleary	173
Olympia	1380
Yelm	279
Shelton	318
Port Townsend	170

Figure 5-5. Cancer risk from on-road diesel sources for each of the study areas.

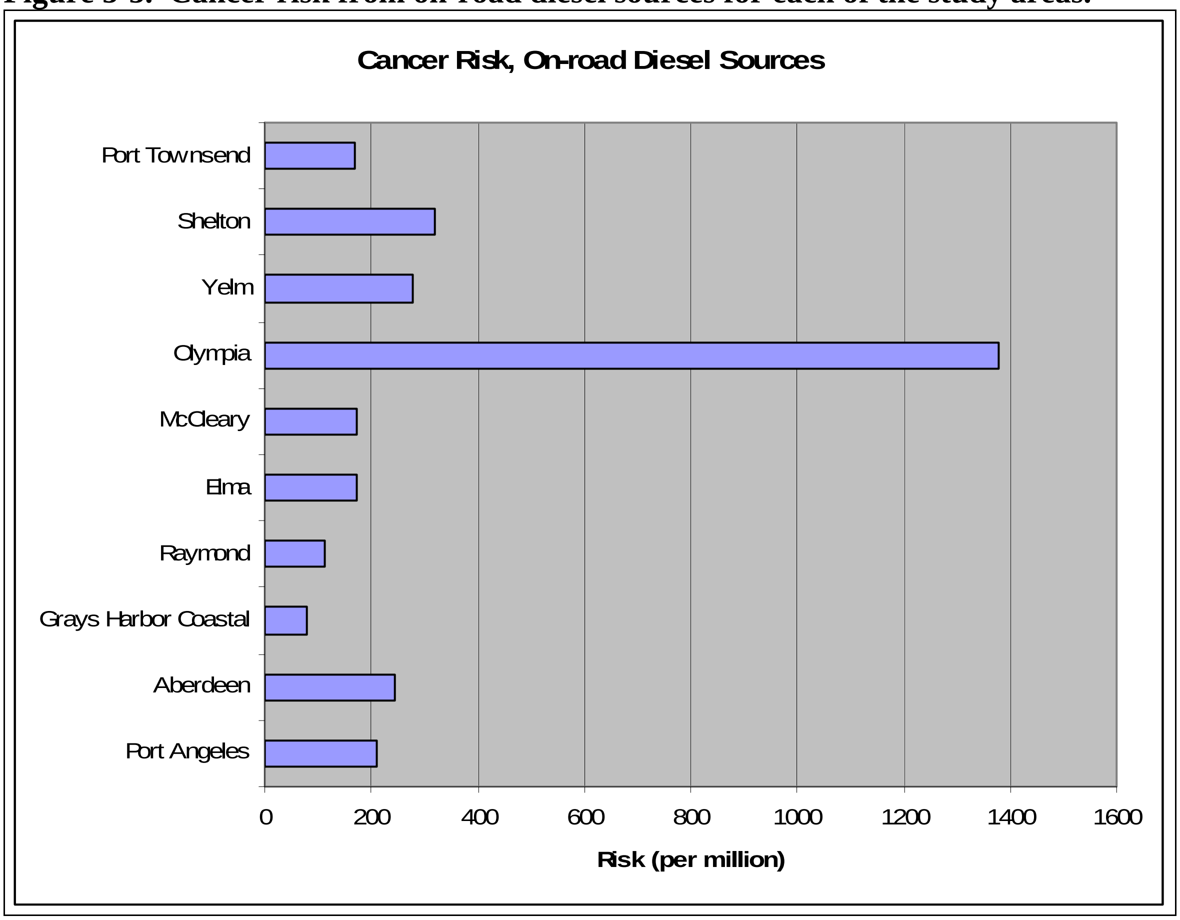


Table 5-5. Dominant chemicals for cancer risk from diesel on-road sources for Port Angeles. Data for Port Angeles is presented to show a typical distribution of risk among the various chemicals. The risk is highly dominated by diesel particulate matter.

CAS	*Chemical*	*Cancer Risk*
9901	Diesel engine exhaust, particulate matter	2.09E-04
106990	1,3-Butadiene	1.22E-06
50000	Formaldehyde	5.14E-07
71432	Benzene	3.60E-07
50328	Benzo[a]pyrene	3.07E-07
18540299	Chromium, hexavalent (& compounds)	1.07E-07
75070	Acetaldehyde	8.98E-08
56553	Benz[a]anthracene	8.89E-08
57117314	2,3,4,7,8-Pentachlorodibenzofuran	4.55E-08
1746016	2,3,7,8-Tetrachlorodibenzo-p-dioxin	4.08E-08
40321764	1,2,3,7,8-Pentachlorodibenzo-p-dioxin	3.45E-08
205992	Benzo[b]fluoranthene	2.85E-08
207089	Benzo[k]fluoranthene	2.85E-08
91203	Naphthalene	2.83E-08
19408743	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	1.75E-08
70648269	1,2,3,4,7,8-Hexachlorodibenzofuran	1.54E-08
35822469	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	1.15E-08
51207319	2,3,7,8-Tetrachlorodibenzofuran	1.03E-08
60851345	2,3,4,6,7,8-Hexachlorodibenzofuran	1.01E-08
57653857	1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin	9.54E-09
57117449	1,2,3,6,7,8-Hexachlorodibenzofuran	7.01E-09
39227286	1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin	4.86E-09
72918219	1,2,3,7,8,9-Hexachlorodibenzofuran	4.08E-09
193395	Indeno[1,2,3-cd]pyrene	3.47E-09
67562394	1,2,3,4,6,7,8-Heptachlorodibenzofuran	3.18E-09
57117416	1,2,3,7,8-Pentachlorodibenzofuran	2.06E-09
218019	Chrysene	1.86E-09
7440020	Nickel	9.57E-10
3268879	1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin	5.28E-10
53703	Dibenz[a,h]anthracene	3.97E-10
55673897	1,2,3,4,7,8,9-Heptachlorodibenzofuran	3.62E-10
39001020	1,2,3,4,6,7,8,9-Octachlorodibenzofuran	3.63E-11

5.3.1.4 On-road Gasoline Sources

Table 5-6. Cancer risk from on-road gasoline sources for each of the study areas.

Study Area	PMI Cancer Risk from Point Sources (Commercial)
Port Angeles	86
Aberdeen	101
Grays Harbor Coastal	33
Raymond	45
Elma	72
McCleary	71
Olympia	576
Yelm	116
Shelton	132
Port Townsend	68

Figure 5-6. Cancer risk from on-road gasoline sources for each of the study areas.

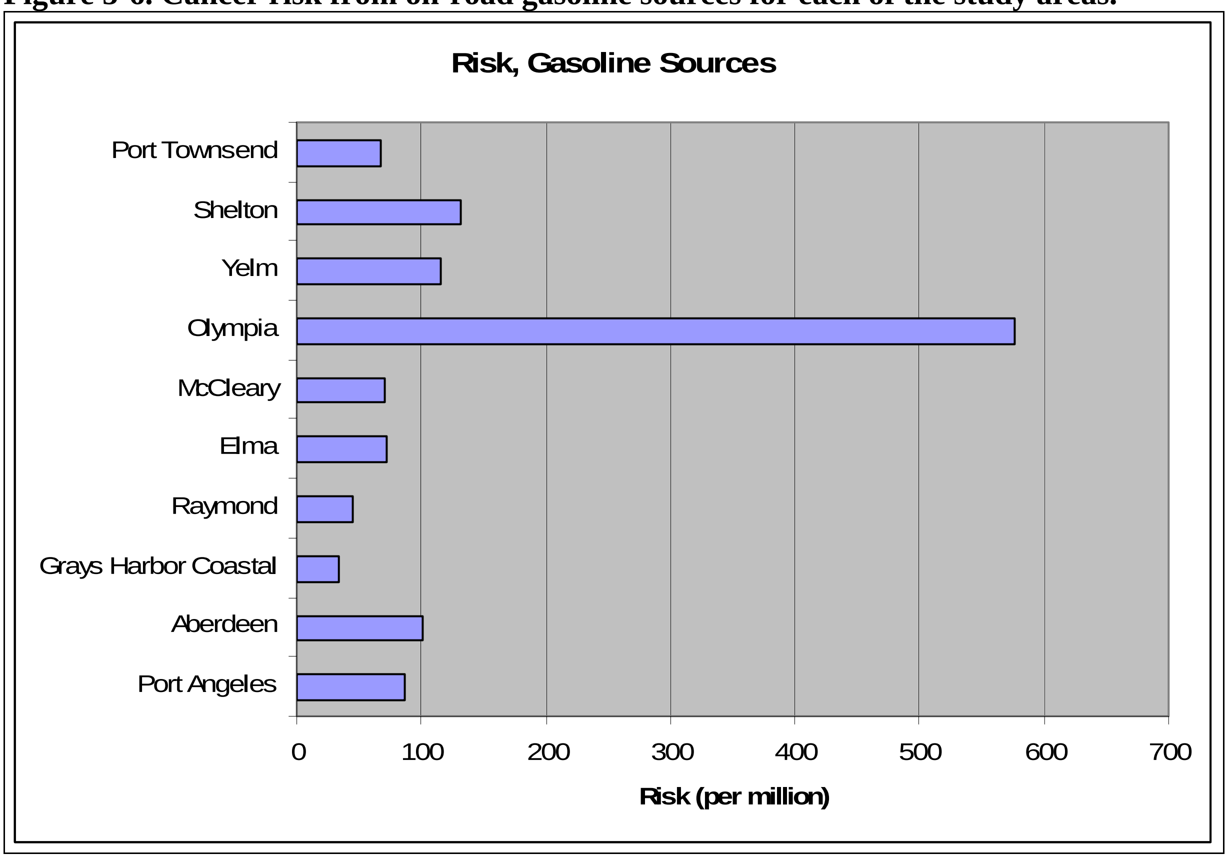


Table 5-7. Dominant chemicals for cancer risk from gasoline on-road sources for Port Angeles. Data for Port Angeles is presented to show a typical distribution of risk among the various chemicals.

CAS	*Chemical*	*Cancer Risk*
50000	Formaldehyde	4.87E-05
50328	Benzo[a]pyrene	2.82E-05
53703	Dibenz[a,h]anthracene	3.92E-06
56553	Benz[a]anthracene	2.69E-06
71432	Benzene	7.92E-07
75070	Acetaldehyde	7.50E-07
91203	Naphthalene	4.78E-07
100414	Ethyl benzene	9.40E-08
100425	Styrene	9.40E-08
106990	1,3-Butadiene	7.92E-08
107028	Acrolein	5.94E-08
108883	Toluene	1.27E-08
110543	Hexane	7.92E-09
193395	Indeno[1,2,3-cd]pyrene	5.97E-09
205992	Benzo[b]fluoranthene	3.74E-09
207089	Benzo[k]fluoranthene	3.49E-09
218019	Chrysene	2.67E-09
630080	Carbon monoxide	1.99E-09
1330207	XYLENES (mixed xylenes)	9.81E-10
1634044	Methyl tert-butyl ether	8.73E-10
1746016	2,3,7,8-Tetrachlorodibenzo-p-dioxin	8.37E-10
3268879	1,2,3,4,6,7,8,9-Octachlorodibenzo-p-dioxin	7.87E-10
7439965	Manganese	5.72E-10
7440020	Nickel	4.76E-10
7446095	SULFUR DIOXIDE	4.29E-10
7664417	Ammonia	3.56E-10
10102440	NITROGEN DIOXIDE	2.79E-10
18540299	Chromium, hexavalent (& compounds)	2.29E-10
19408743	1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin	3.39E-11
35822469	1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin	2.79E-11
39001020	1,2,3,4,6,7,8,9-Octachlorodibenzofuran	9.89E-12

5.3.1.5 Wood Stove Sources

Table 5-9 shows the chemicals that contribute to cancer risk from wood stove and fireplace sources, in descending order of cancer risk, at the PMI for Port Angeles. Note the relative magnitude of risk from the three pathways (inhalation, dermal exposure, soil ingestion).

Cancer risk from wood stoves typically reaches a value of 200 to 400 in densely populated areas. The maps in section 5.2 show results for each of the study areas.

Table 5-8. Cancer risk from wood stoves for each of the study areas.

Study Area	PMI Cancer Risk from Point Sources (Commercial)
Port Angeles	269
Aberdeen	200
Grays Harbor Coastal	73
Raymond	79
Elma	167
McCleary	84
Olympia	450
Yelm	197
Shelton	218
Port Townsend	181

Figure 5-7. Cancer risk from wood stoves for each of the study areas.

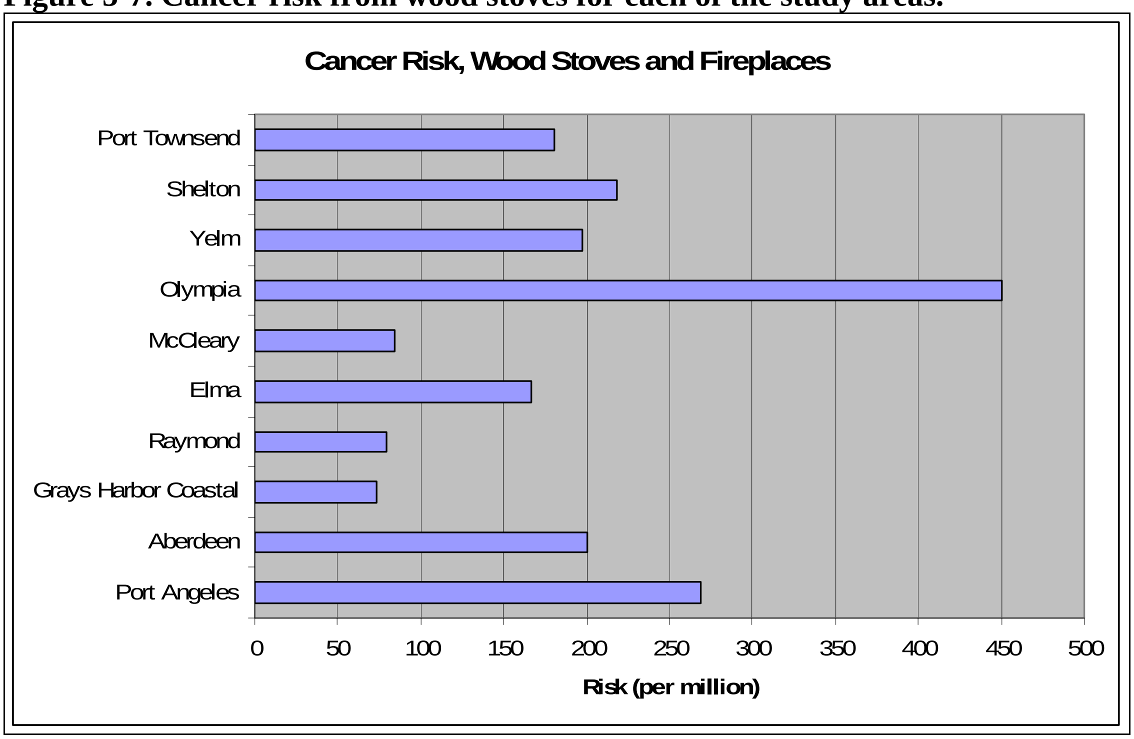


Table 5-9. Dominant chemicals for cancer risk from wood stove sources for Port Angeles. Data for Port Angeles is presented to show a typical distribution of risk among the various chemicals.

CAS	Chemical	INHAL	DERM	SOIL	TOTAL
246	Polycyclic Organic Matter	1.47E-05	1.59E-04	2.38E-05	1.98E-04
50328	Benzo[a]pyrene	6.13E-07	2.04E-05	3.05E-06	2.40E-05
53703	Dibenz[a,h]anthracene	9.72E-07	1.05E-05	1.57E-06	1.30E-05
56495	3-Methylcholanthrene	2.40E-07	7.99E-06	1.20E-06	9.43E-06
56553	Benz[a]anthracene	6.91E-06	0.00E+00	0.00E+00	6.91E-06
57976	7,12-Dimethylbenz[a]anthracene	9.76E-08	3.25E-06	4.86E-07	3.83E-06
71432	Benzene	8.72E-08	2.90E-06	4.34E-07	3.42E-06
78933	Methyl ethyl ketone {2-Butanone}	7.19E-08	2.39E-06	3.58E-07	2.82E-06
91203	Naphthalene	6.89E-08	2.29E-06	3.43E-07	2.70E-06
95476	o-Xylene	1.81E-07	1.96E-06	2.93E-07	2.43E-06
108883	Toluene	1.13E-06	0.00E+00	0.00E+00	1.13E-06
108952	Phenol	2.49E-08	8.28E-07	1.24E-07	9.77E-07
193395	Indeno[1,2,3-cd]pyrene	1.55E-08	5.16E-07	7.73E-08	6.09E-07
205823	Benzo[j]fluoranthene	1.58E-08	0.00E+00	0.00E+00	1.58E-08
205992	Benzo[b]fluoranthene	4.62E-10	0.00E+00	0.00E+00	4.62E-10
207089	Benzo[k]fluoranthene	0.00E+00	0.00E+00	0.00E+00	0.00E+00
218019	Chrysene	0.00E+00	0.00E+00	0.00E+00	0.00E+00
630080	Carbon monoxide	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7439965	Manganese	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7440020	Nickel	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7440439	Cadmium	0.00E+00	0.00E+00	0.00E+00	0.00E+00
7446095	SULFUR DIOXIDE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
10102440	NITROGEN DIOXIDE	0.00E+00	0.00E+00	0.00E+00	0.00E+00
TOTAL		2.52E-05	2.12E-04	3.18E-05	2.69E-04

It is worthwhile to compare these results with the estimated wood stove cancer risk values from reference [2] (*Puget Sound Air Toxics Evaluation).* Reference [2] shows risk values in the range of 60-100 per million for the area, based on monitoring data. The results shown above indicate a substantially higher risk of 269 per million (for this example only, Port Angeles; the risk can be higher in other areas). The difference between these two estimates can be attributed to the inclusion of additional exposure pathways in our analysis (soil ingestion and dermal exposure).

In reference [2] the risk values are based on a unit risk factor [1/(ug/m3)] for wood smoke. The cancer risk is estimated by multiplying the unit risk factor by the ground level concentration [ug/m3]. Unit risk factors typically account for only the inhalation pathway. The analysis presented here uses instead a cancer slope factor [1/(mg/(kg-day))]. Cancer is computed by multiplying the human dose [mg/(kg-day)] by the slope factor. Inhalation dose is computed from the ground level concentration and estimates of the human inhalation rate and body weight. In addition, our analysis includes the dermal exposure and soil ingestion pathways, following the OEHHA guidelines. To illuminate the effect of these two addition pathways, Table 5-9 shows the contributions from each of the three pathways. It can be seen that the estimated contribution to risk from the dermal pathway is several times higher than the risk through inhalation.

To put the two results (ours and reference [2]) on an equal footing for comparison purposes, the analysis of wood stove risk was repeated, excluding the dermal and soil pathways. Figure 5-8 is a contour map of cancer risk showing the result. The PMI cancer risk is 27 per million, which is more consistent with the estimate in reference [2]. Note that risk from wood stoves can vary substantially from one study area to another depending on the concentration of residents who burn wood fuel. The maximum risk from wood stove in Olympia, for example, is about twice as high as for Port Angeles.

Note also that in reference [2] wood smoke was treated as a single chemical having a unit risk factor of 1.0E-5. In our study the wood stove and fireplace emissions were speciated, the cancer risk was computed for each individual chemical using the appropriate slope factors, and the cancer risk from all of the chemicals was summed. We would conclude that the aggregate unit risk factor for smoke used in reference [2] is a good estimate of the combined effects of all of the chemicals, but does not account for pathways other than inhalation.

Figure 5-8. Contour map of cancer risk from wood smoke including inhalation, soil and dermal pathways (Port Angeles). Maximum risk = 269 per million.

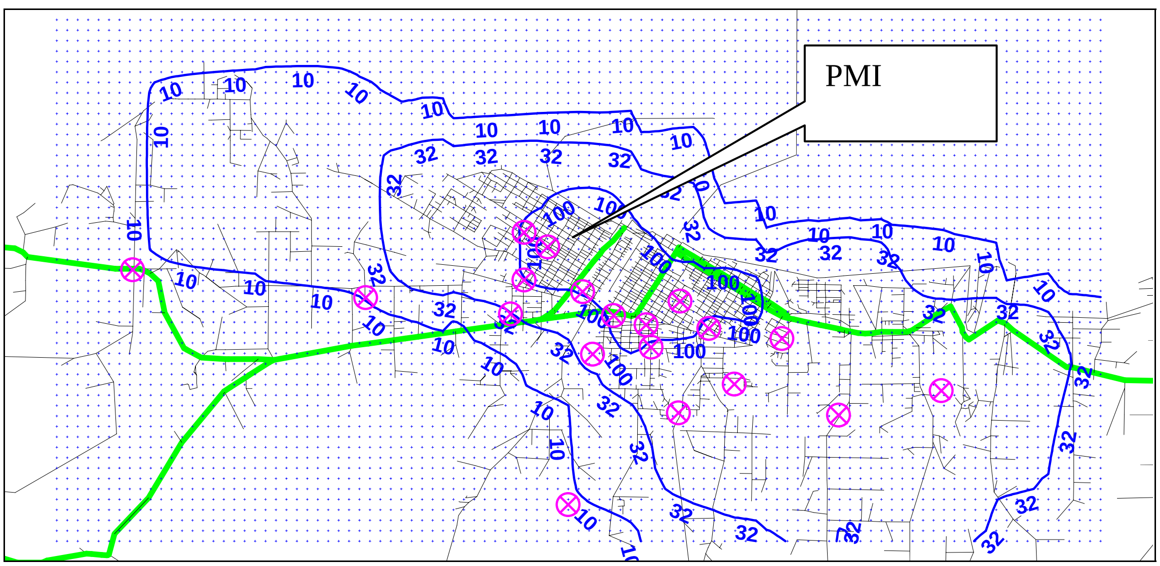
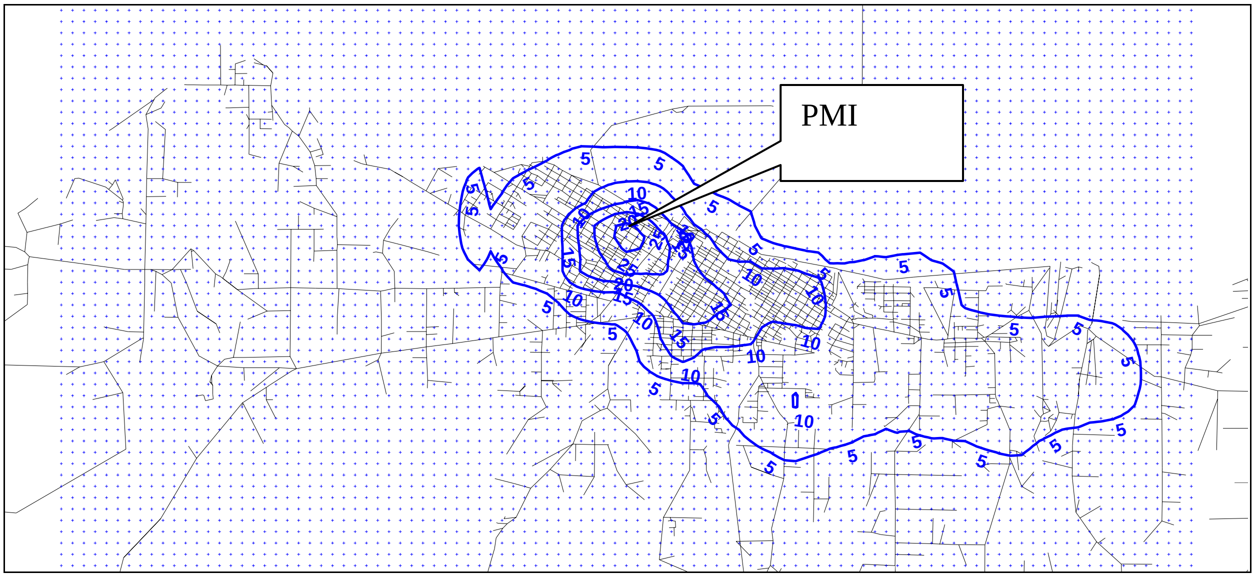


Table 5-10. Contour map of cancer risk from wood smoke after eliminating non-inhalation pathways (Port Angeles). Maximum risk = 27 per million.



5.3.2 Chronic Non-cancer Risk

5.3.2.1 All Sources

The following table and figures show the chronic non-cancer risk at the PMI for each of the study areas. The chronic non-cancer risk PMI is typically on a freeway, artery or collector. The risk drops off rapidly within a few hundred meters of the roadway. Refer to the details for each study area in section 5.4.

Table 5-11. Summary of chronic non-cancer risk, all sources, by area.

Study Area	***Chronic HHI at PMI for each study area***
Port Angeles	1.05
Aberdeen	1.40
Grays Harbor Coastal	0.33
Raymond	0.46
Elma	0.72
McCleary	0.72
Olympia	5.96
Yelm	1.17
Shelton	2.68
Port Townsend	0.69

Figure 5-9. Summary of chronic non-cancer risk, all sources, by area.

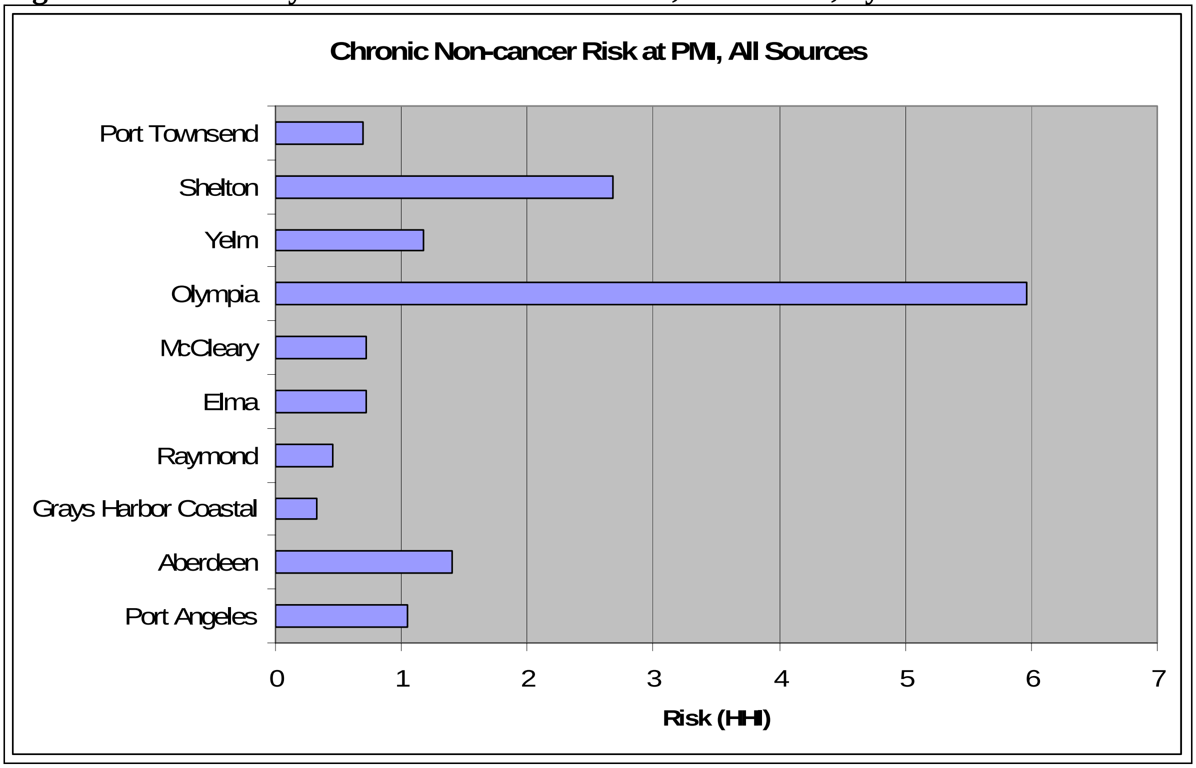
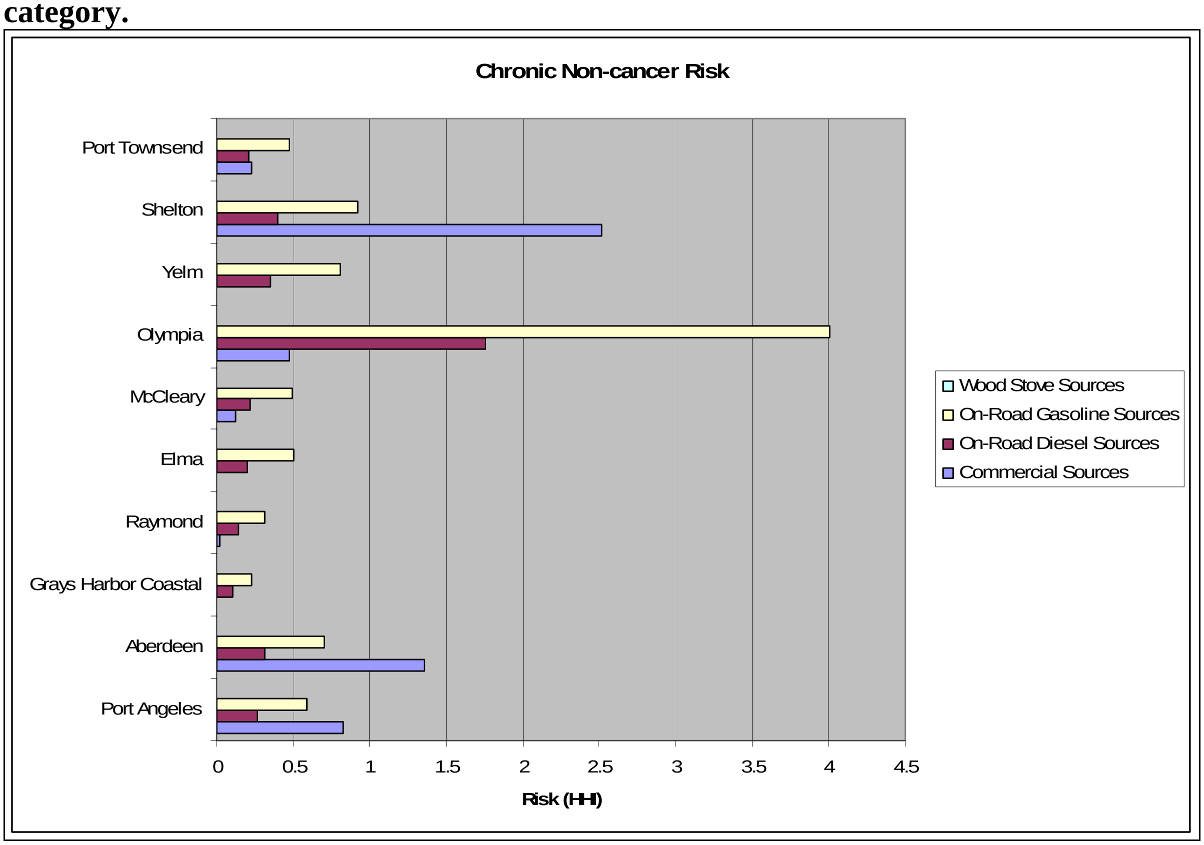


Figure 5-10. Summary of chronic non-cancer risk, all sources, by area, broken down source category.



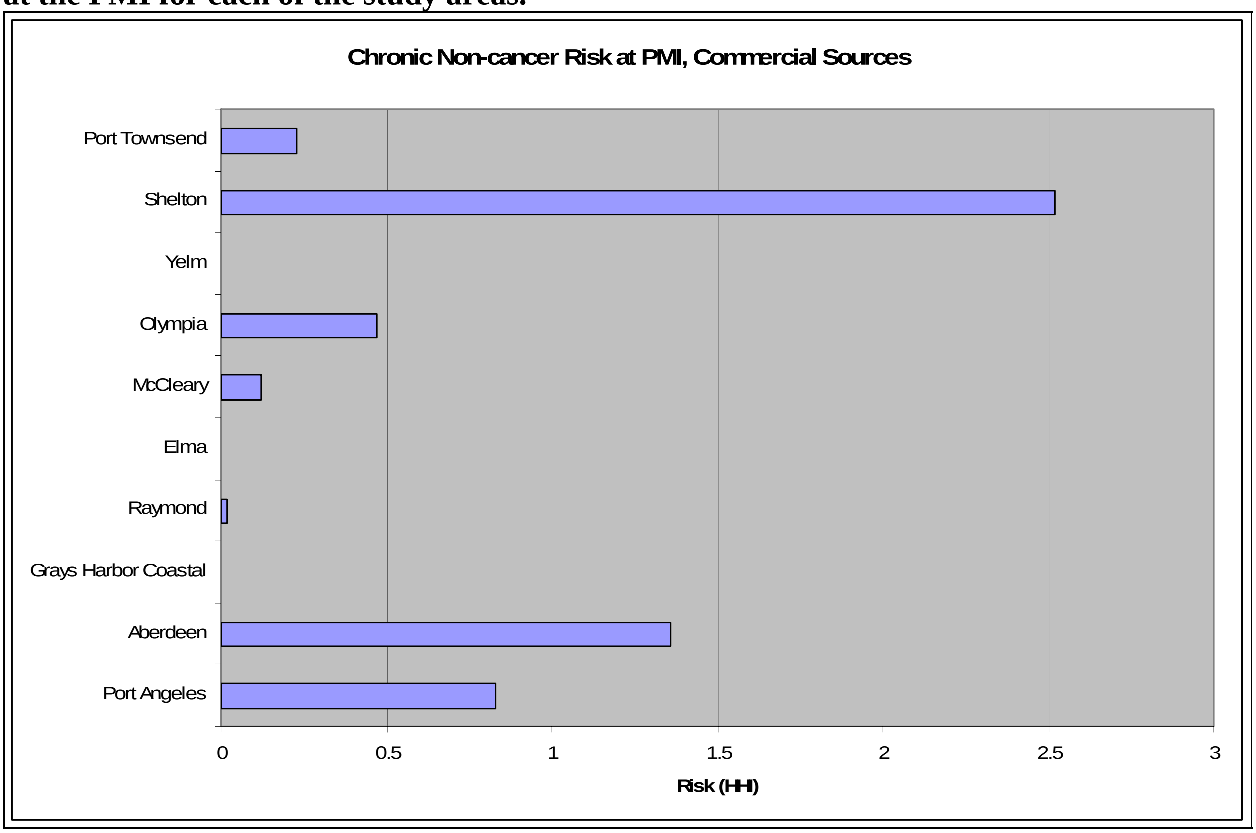
5.3.2.2 Point Sources

Chronic non-cancer risk from commercial point sources varies from one region to another. The results for each region are shown in section 5.4. The following table summarizes the chronic non-cancer risk from point sources in each of the study areas.

Table 5-12. Chronic non-cancer risk health hazard index (HHI) from commercial sources at the PMI for each of the study areas.

Study Area	*PMI Chronic HHI from Point Sources (Commercial)*
Port Angeles	0.83
Aberdeen	1.36
Grays Harbor Coastal	<0.01
Raymond	0.02
Elma	<0.01
McCleary	0.12
Olympia	0.47
Yelm	<0.01
Shelton	2.52
Port Townsend	0.23

Figure 5-11. Chronic non-cancer risk health hazard index (HHI) from commercial sources at the PMI for each of the study areas.



The following table lists the chemicals that are the largest contributors to chronic non-cancer risk at the PMI in Port Angeles.

Table 5-13. Chemicals contributing to chronic non-cancer risk from commercial sources at PMI for Port Angeles.

CAS	*Chemical*	*Chronic HHI*
107028	Acrolein	7.21E-01
7439965	Manganese	8.68E-02
7782505	Chlorine	4.27E-02
50000	Formaldehyde	4.15E-02
7439976	Mercury	3.81E-02
7440382	Arsenic	2.92E-02
7446095	SULFUR DIOXIDE	1.08E-02
10102440	NITROGEN DIOXIDE	7.84E-03
75070	Acetaldehyde	6.72E-03
7440439	Cadmium	3.50E-03
7647010	Hydrochloric acid	3.05E-03
108952	Phenol	1.67E-03
71432	Benzene	7.58E-04
7440417	Beryllium	5.38E-04
18540299	Chromium, hexavalent (& compounds)	2.31E-04
67561	Methanol	3.58E-05
108883	Toluene	3.33E-05
100425	Styrene	2.66E-05
56235	Carbon tetrachloride	8.92E-06
75092	Methylene chloride {Dichloromethane}	7.87E-06
75014	Vinyl chloride	5.71E-06
7440666	Zinc	1.41E-06
1330207	XYLENES (mixed xylenes)	1.33E-07
100414	Ethyl benzene	3.81E-08
50328	Benzo[a]pyrene	0.00E+00
630080	Carbon monoxide	0.00E+00
7439921	Lead	0.00E+00
TOTAL		8.37E-01

5.3.2.3 On-road Diesel Sources

The following table shows the chemicals that dominate chronic non-cancer risk from on-road diesel sources, in descending order of risk, at the PMI for Port Angeles. The chronic HHI at the PMI is 0.27. Chronic non-cancer risk can vary substantially from one study area to another, and will be higher where several major roads intersect. Section 5.4 contains contour plots of chronic non-cancer risk for each of the study areas.

Table 5-14. Chronic non-cancer risk from diesel on-road sources for each of the study areas.

Study Area	***PMI Chronic HHI from On-road Diesel Sources***
Port Angeles	0.27
Aberdeen	0.31
Grays Harbor Coastal	0.10
Raymond	0.14
Elma	0.20
McCleary	0.22
Olympia	1.76
Yelm	0.35
Shelton	0.40
Port Townsend	0.21

Figure 5-12. Chronic non-cancer risk from diesel on-road sources for each of the study areas.

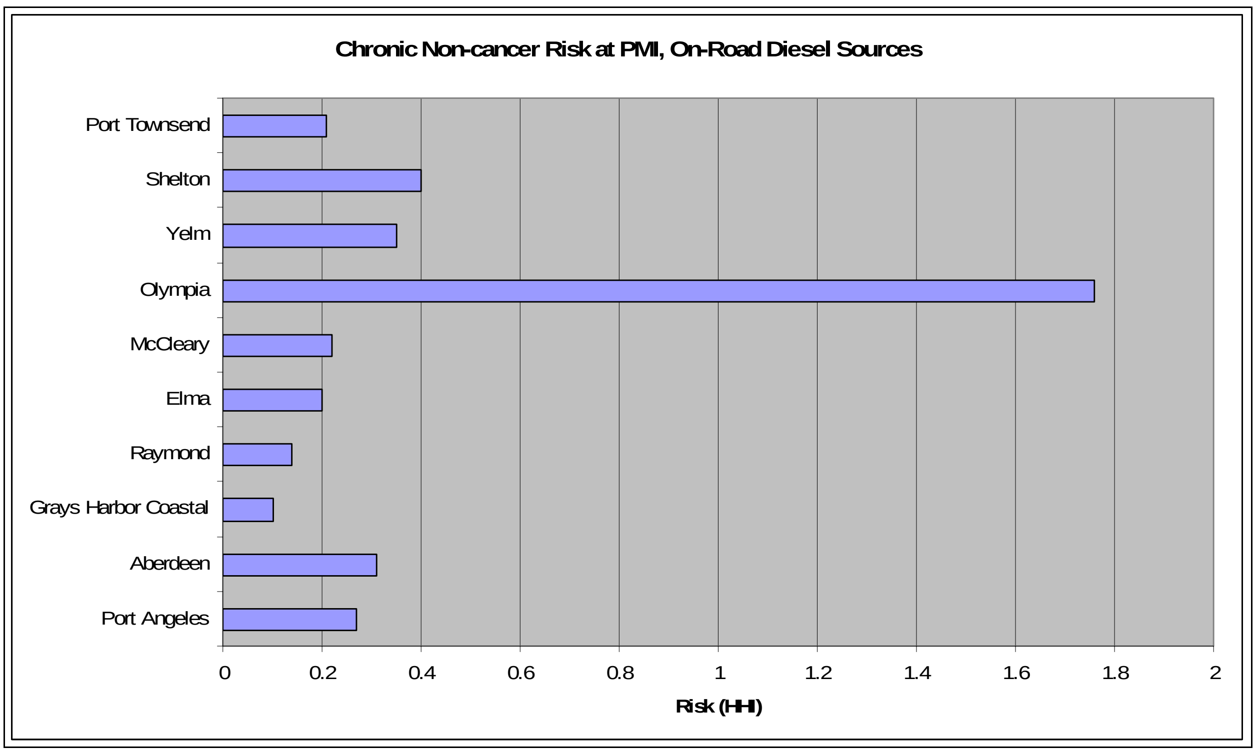


Table 5-15. Dominant chemicals contributing to chronic non-cancer risk from diesel on-road sources for Port Angeles.

CAS	***Chemical***	***Chronic HHI***
9901	Diesel engine exhaust, particulate matter	1.31E-01
107028	Acrolein	6.52E-02
10102440	NITROGEN DIOXIDE	4.15E-02
50000	Formaldehyde	2.82E-02
75070	Acetaldehyde	3.44E-03
7446095	SULFUR DIOXIDE	5.45E-04
106990	1,3-Butadiene	3.52E-04
71432	Benzene	2.07E-04
7664417	Ammonia	1.81E-04

5.3.2.4 On-road Gasoline Sources

The following table shows the chemicals that dominate chronic non-cancer risk from on-road gasoline sources for Port Angeles.

Table 5-16. Chronic non-cancer risk from on-road gasoline sources for each of the study areas.

Study Area	***PMI Chronic HHI from On-road Gasoline Sources***
Port Angeles	0.59
Aberdeen	0.70
Grays Harbor Coastal	0.23
Raymond	0.31
Elma	0.50
McCleary	0.49
Olympia	4.01
Yelm	0.81
Shelton	0.92
Port Townsend	0.47

Figure 5-13. Chronic non-cancer risk from on-road gasoline sources for each of the study areas.

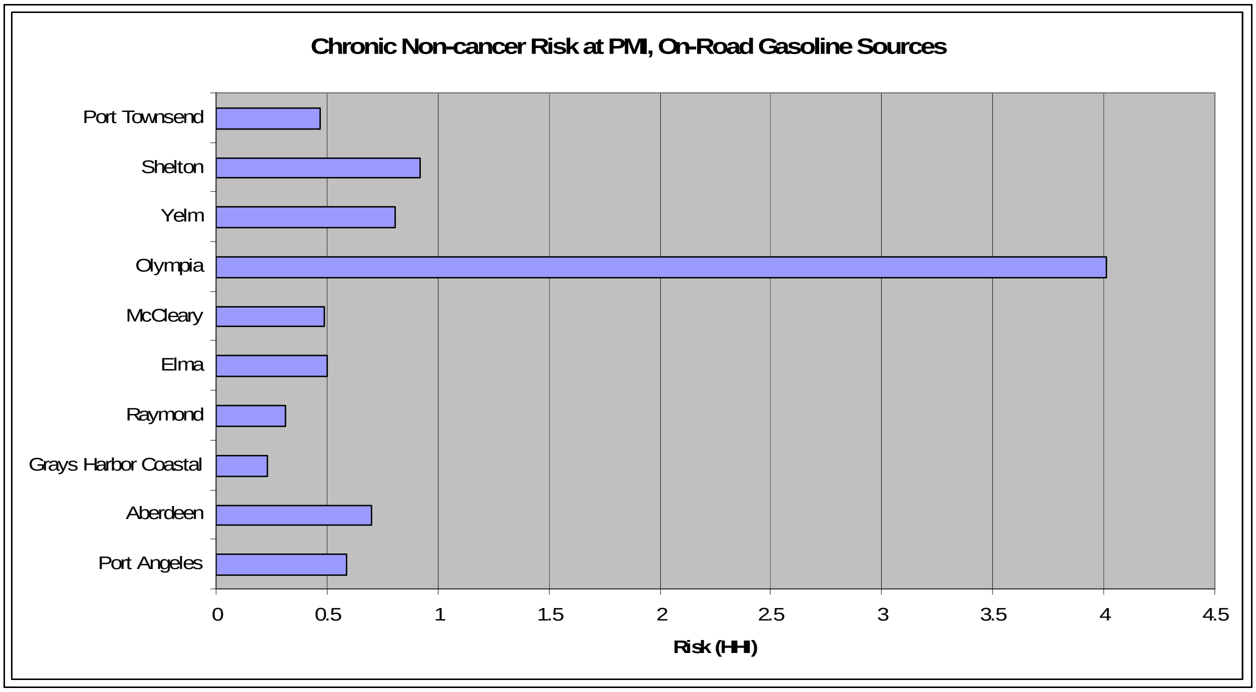


Table 5-17. Dominant chemicals contributing to chronic non-cancer risk from gasoline on-road sources for Port Angeles.

CAS	*Chemicals*	*Chronic HHI*
50000	Formaldehyde	3.39E-01
50328	Benzo[a]pyrene	1.47E-01
53703	Dibenz[a,h]anthracene	6.45E-02
56553	Benz[a]anthracene	2.80E-02
71432	Benzene	1.83E-02
75070	Acetaldehyde	1.28E-02
91203	Naphthalene	8.12E-03
100414	Ethyl benzene	6.18E-03
100425	Styrene	3.09E-03
106990	1,3-Butadiene	2.40E-03
107028	Acrolein	1.61E-03
108883	Toluene	9.66E-04
110543	Hexane	2.81E-04
193395	Indeno[1,2,3-cd]pyrene	1.33E-04
205992	Benzo[b]fluoranthene	1.25E-04
207089	Benzo[k]fluoranthene	1.11E-04

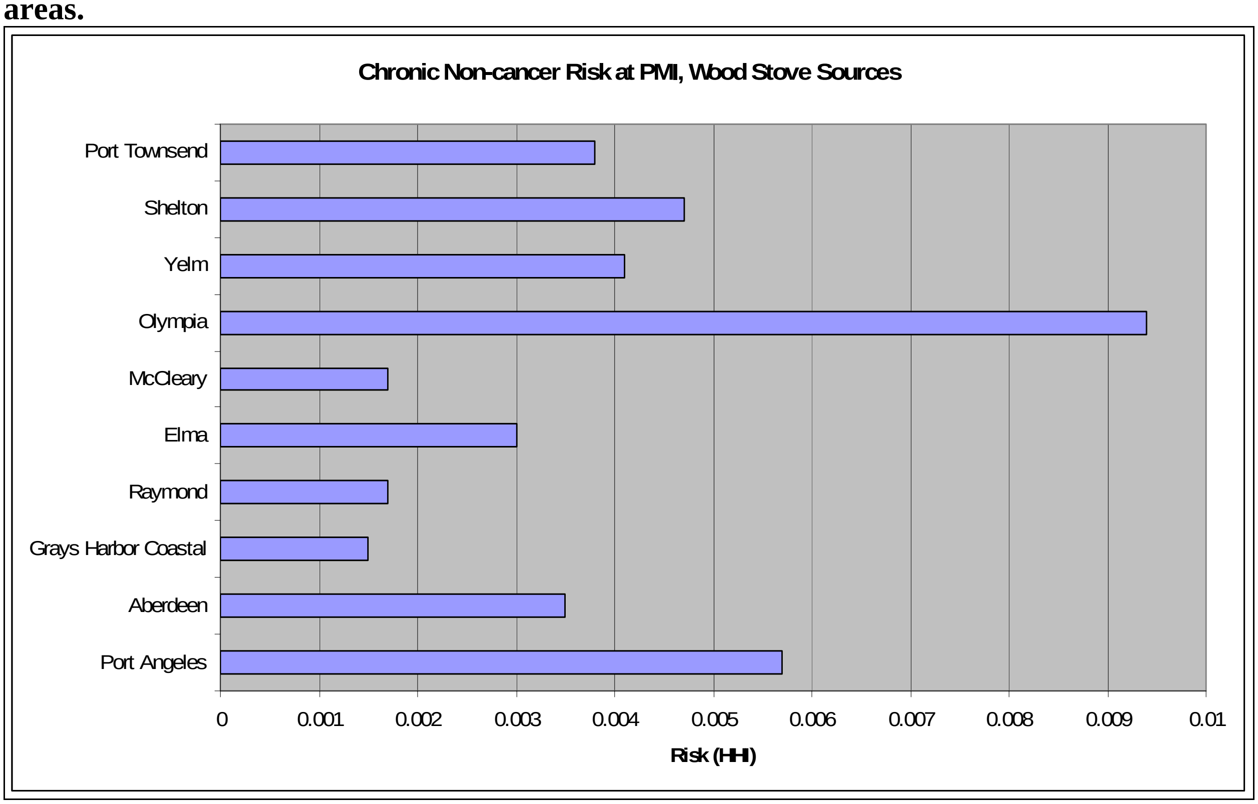
5.3.2.5 Wood Stove Sources

As the following table shows, the chronic non-cancer risk from wood stoves in insignificant in all of the study areas.

Table 5-18. Chronic non-cancer risk from wood stoves and fireplaces for each of the study areas.

Study Area	*PMI Chronic HHI from Wood Stove Sources*
Port Angeles	0.0057
Aberdeen	0.0035
Grays Harbor Coastal	0.0015
Raymond	0.0017
Elma	0.0030
McCleary	0.0017
Olympia	0.0094
Yelm	0.0041
Shelton	0.0047
Port Townsend	0.0038

Figure 5-14. Chronic non-cancer risk from wood stoves and fireplaces for each of the study areas.



5.4 Health Risk Assessment Results by Area

5.4.1 General Description

5.4.1.1 Interpretation of PMI

The maps that follow in this section show where the PMI (Point of Maximum Impact) is located for each of the study areas. It is important to note that the PMI locations that are identified in this analysis do not necessarily correspond to locations where there are residents. The PMIs may fall in commercial areas, or even within the property boundaries of the emitting facilities, or over nearby water.

5.4.1.2 Risk Units

In the following sections, cancer risk is expressed as either a dimensionless probability or as changes per million. For example, a cancer risk of 1.0E-6 (dimensionless probability) might also be expressed as 1 per million.

Chronic non-cancer risk is expressed as a dimensionless health hazard index (HHI). A value exceeding 1.0 is generally considered unacceptable.

5.4.1.3 Symbols

On the maps, small magenta squares are locations of on-road freeway, artery, collector and local road emission sources. Green squares are the boundaries of local road area sources. Blue squares are the boundaries of modeled wood stove emission sources. X's surrounded by circles are the locations of commercial release points (commonly referred to as point sources).

5.4.2 Port Angeles

5.4.2.1 Summary

Figure 5-15. Port Angeles study area.

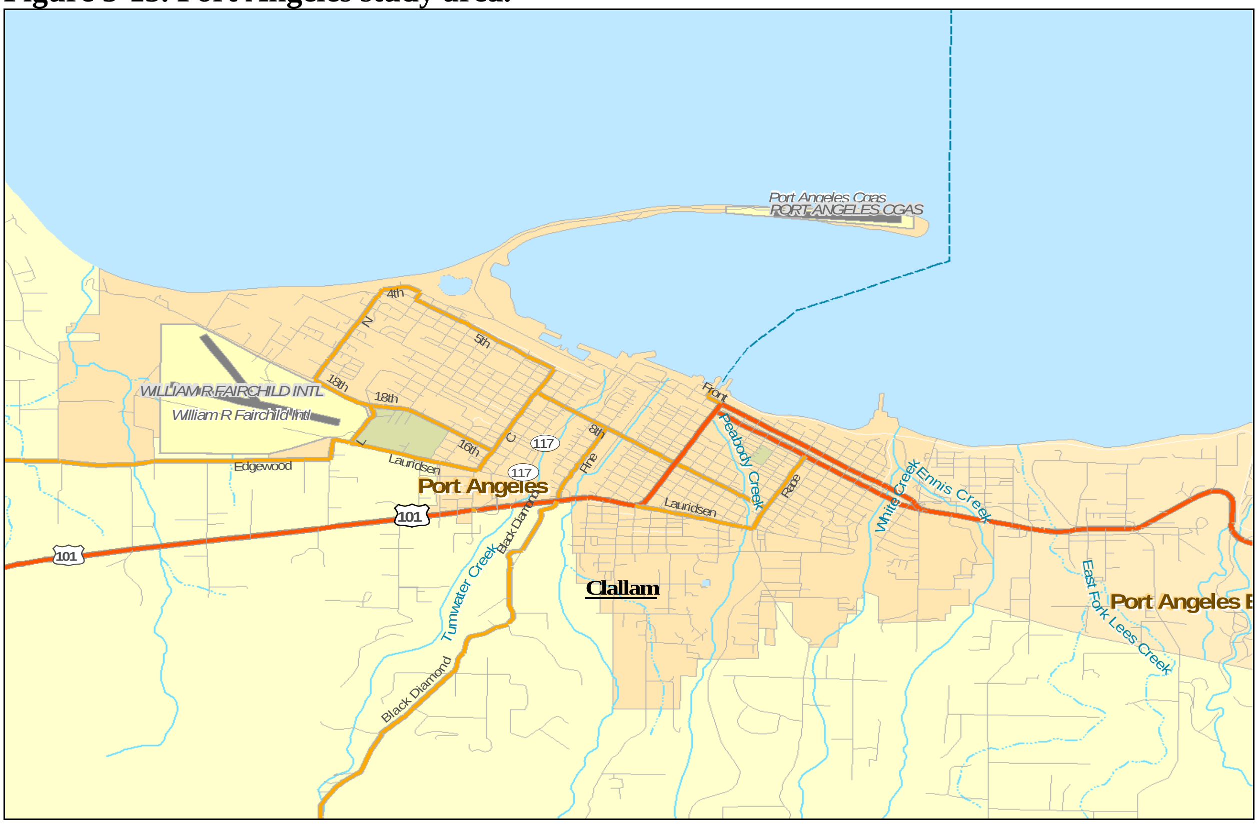
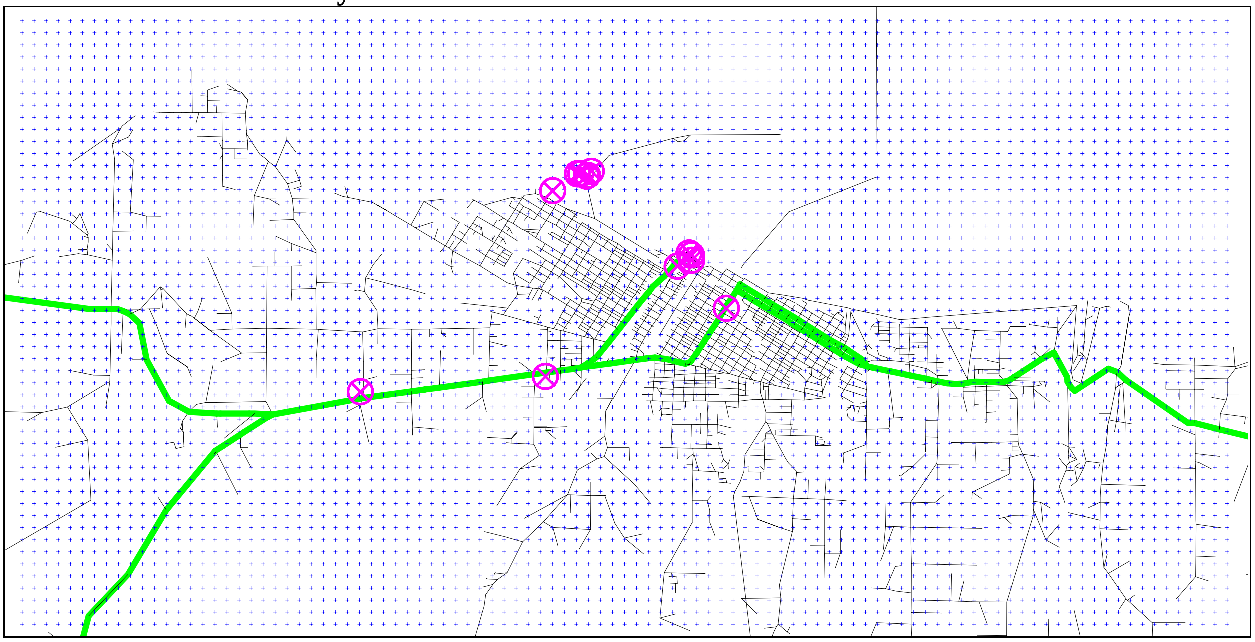


Figure 5-16. Analysis grid and locations of commercial sources, Port Angles. Source locations are indicated by circled X's.



Small magenta squares are locations of on-road freeway, artery, collector and local road sources. (Note that in Port Angeles there are no freeways) Green squares are the boundaries of local road area sources. Blue squares are locations of wood stove sources

Figure 5-17. Locations of non-commercial sources, Port Angles.

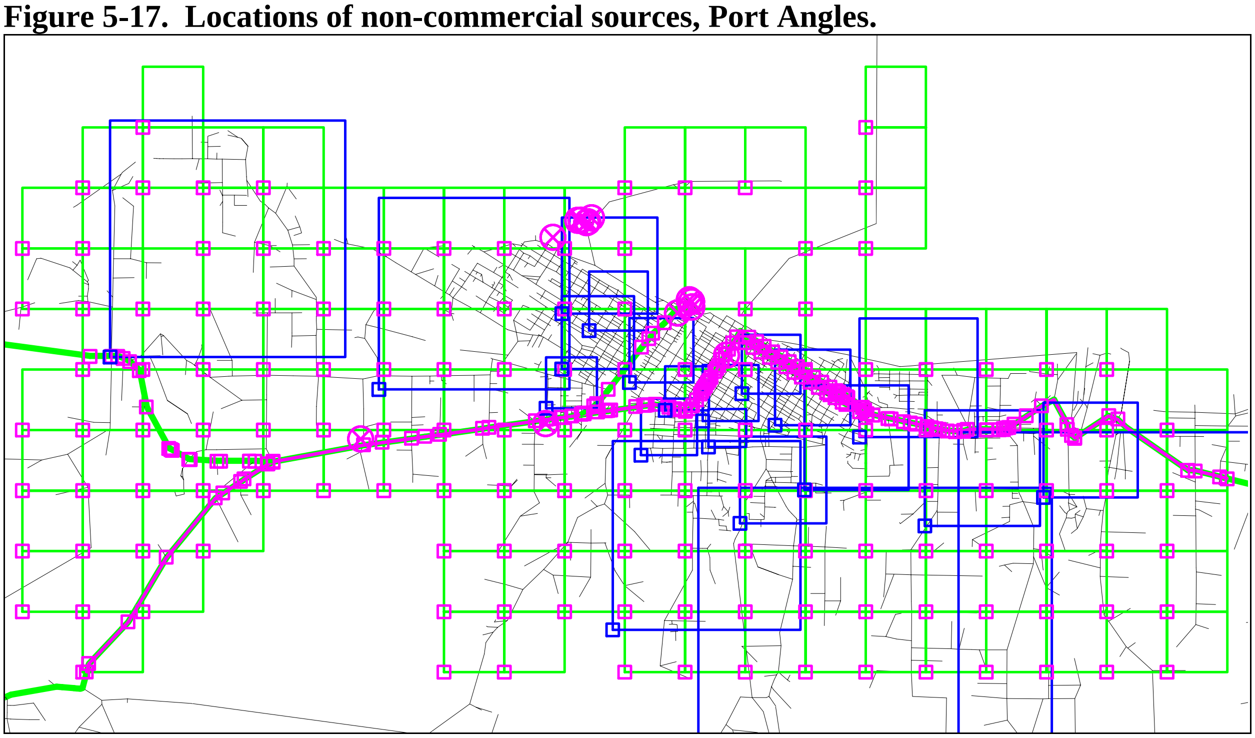


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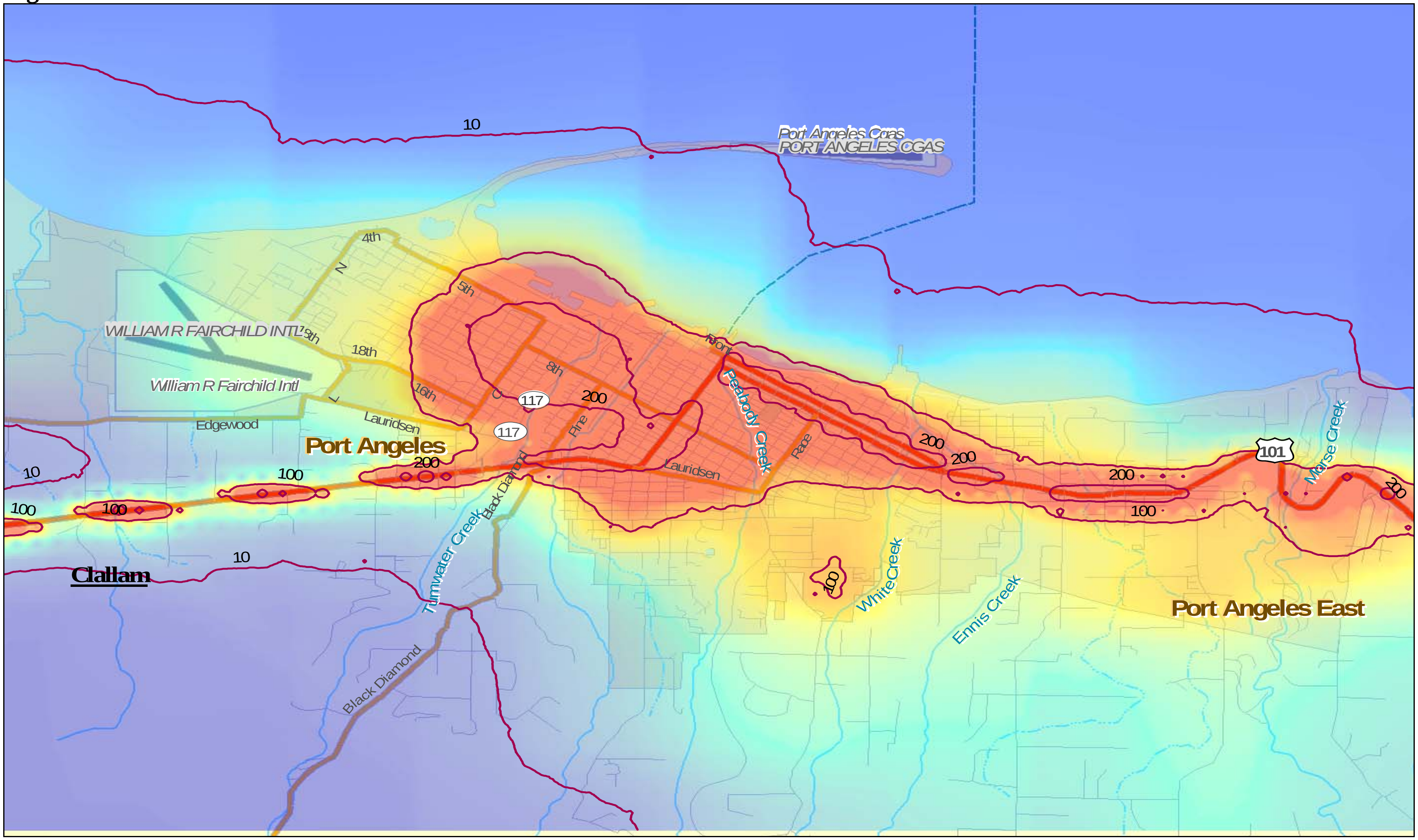
Figure 5-18. Contours of total cancer risk from all sources.



5.4.2.2 Cancer

5.4.2.2.1 Commercial Sources

Table 5-19. Commercial sources included in analysis.

Facility	***Stack***	***UTME***	***UTMN***
		meters	***meters***
NIPPON PAPER INDUSTRIES USA CO LTD	stack 5813	465450	5331504
NIPPON PAPER INDUSTRIES USA CO LTD	stack 5814	464808	5331181
NIPPON PAPER INDUSTRIES USA CO LTD	stack 5812	465219	5331462
NIPPON PAPER INDUSTRIES USA CO LTD	stack 583	465369	5331423
NIPPON PAPER INDUSTRIES USA CO LTD	stack 584	465388	5331438
PLATYPUS MARINE	stack 321	466877	5329932
NIPPON PAPER INDUSTRIES USA CO LTD	stack 588	465273	5331465
K PLY	stack 611	467112	5330119
K PLY	stack 612	467115	5330031
K PLY	stack 615	467073	5330150
LAKESIDE INDUSTRIES - PORT ANGELES	stack 631	464688	5328105
OLYMPIC LAUNDRY	stack 71	467691	5329233
INTERFOR PACIFIC INC	stack 7741	461616	5327851
NIPPON PAPER INDUSTRIES USA CO LTD	stack 586	465377	5331435

Table 5-20. Dominant chemicals contributing to cancer risk, commercial sources.

CAS	***POLLUTANT NAME***	***INHAL***	***DERM***	***SOIL***	***TOTAL***
7440382	Arsenic	8.67E-07	5.78E-06	2.81E-06	9.46E-06
18540299	Chromium, hexavalent	8.89E-06	0.00E+00	0.00E+00	8.89E-06
71432	Benzene	1.71E-06	0.00E+00	0.00E+00	1.71E-06
50328	Benzo[a]pyrene	3.73E-08	1.24E-06	1.86E-07	1.46E-06

Table 5-21. Emissions of dominant chemicals.

Arsenic

Facility	Annual EMS (lbs/yr)
NIPPON PAPER INDUSTRIES USA CO LTD	25
K PLY	6
INTERFOR PACIFIC INC	8

Chromium, hexavalent.

Facility	Annual EMS (lbs/yr)
NIPPON PAPER INDUSTRIES USA CO LTD	4
K PLY	1
INTERFOR PACIFIC INC	1

Benzene

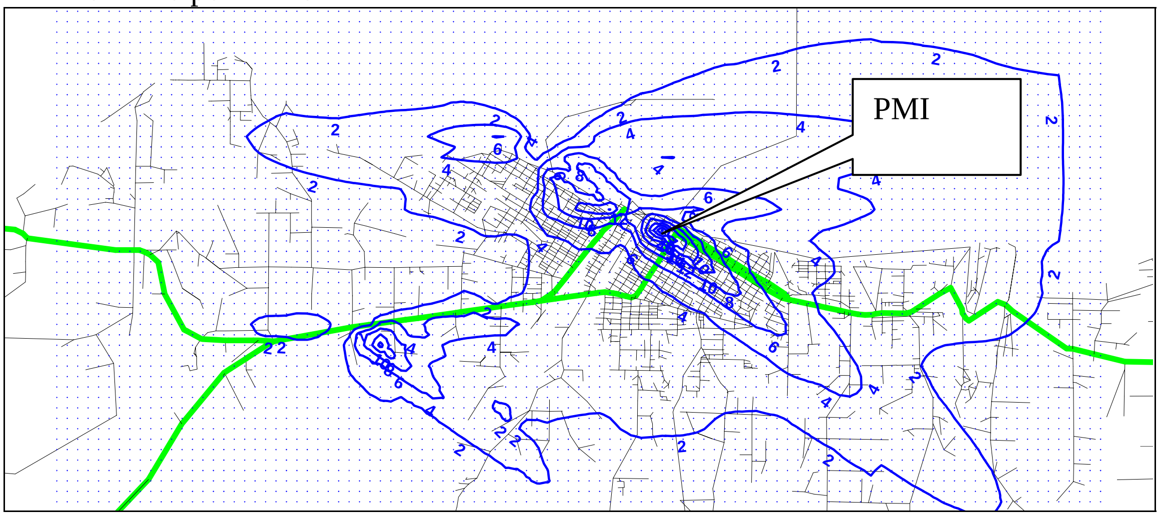
Facility	Annual EMS (lbs/yr)
NIPPON PAPER INDUSTRIES USA CO LTD	3540
INTERFOR PACIFIC INC	1637
K PLY	1081

Emissions of Benzo[a]pyrene

Facility	Annual EMS (lbs/yr)
GRAYS HARBOR PAPER LP	7
NIPPON PAPER INDUSTRIES USA CO LTD	2
K PLY	1

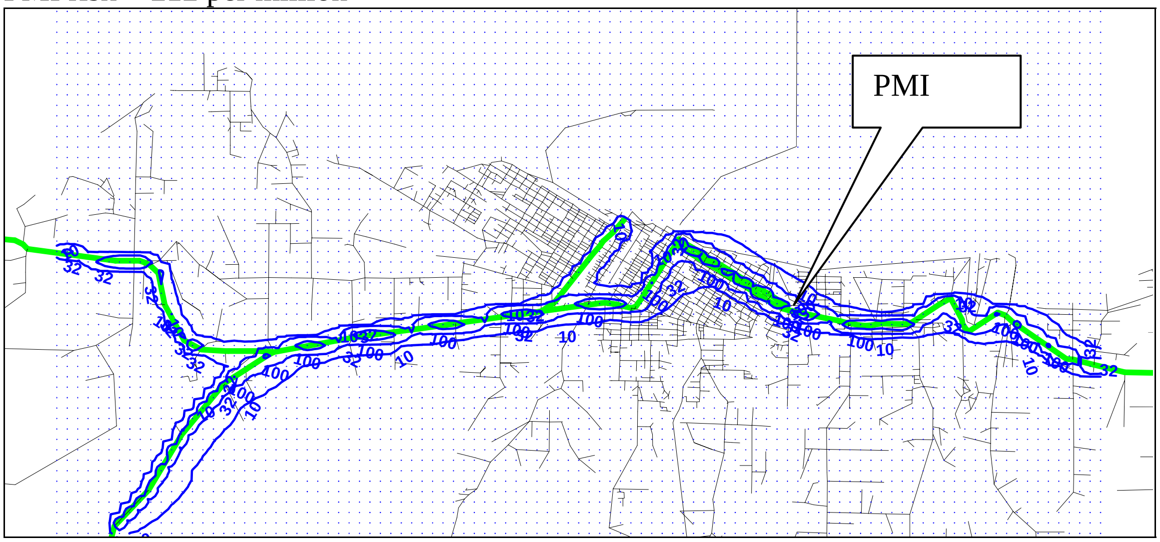
Figure 5-19. Port Angeles, commercial, cancer.

PMI risk = 20 per million



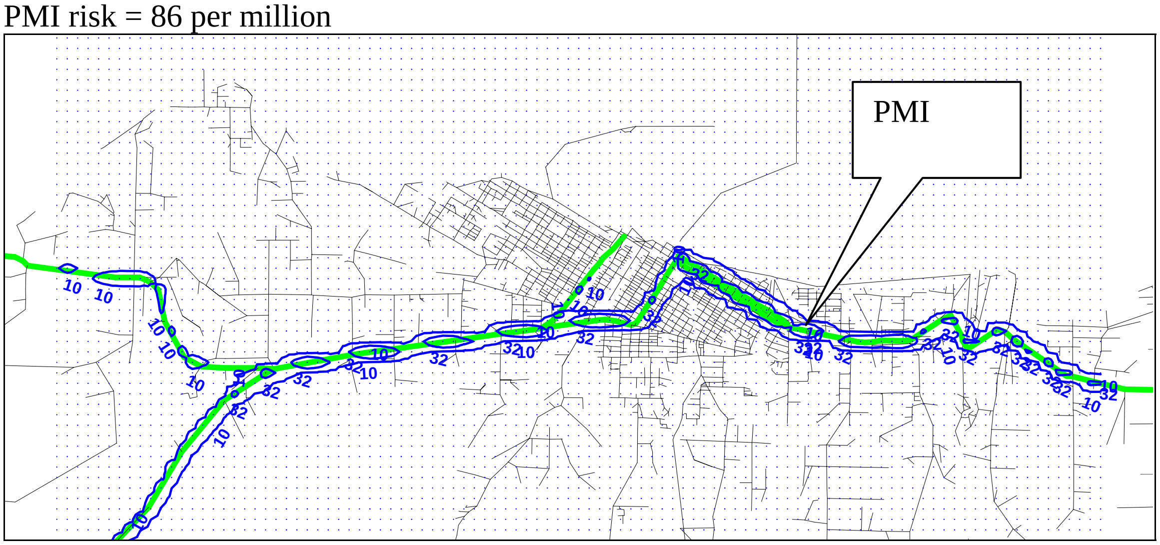
5.4.2.2.2 Diesel On-road

Figure 5-20. Port Angeles, on-road diesel, cancer.
PMI risk = 212 per million



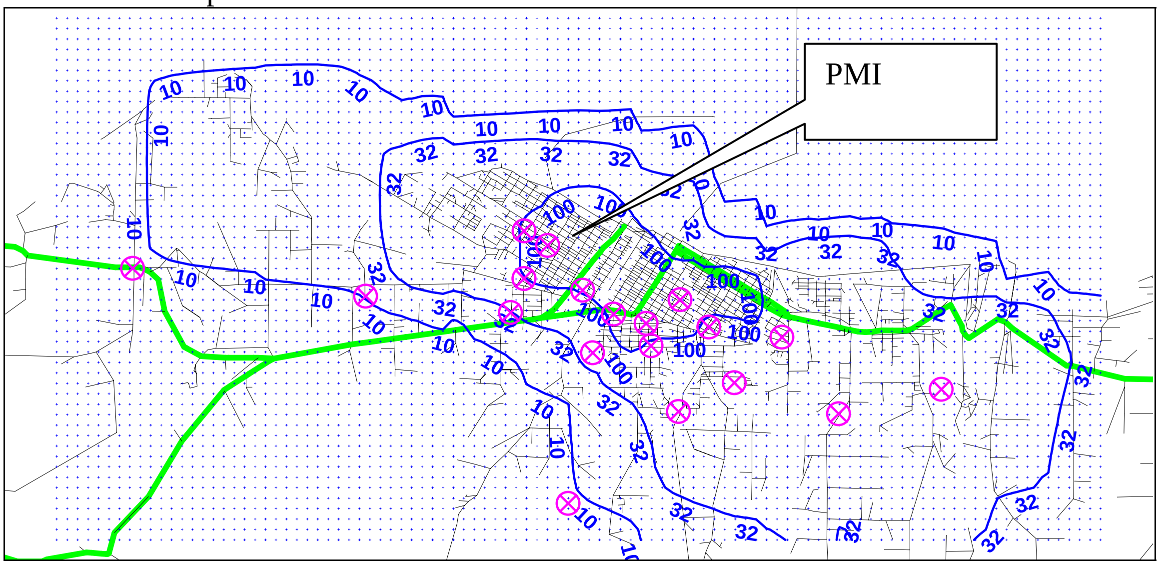
5.4.2.2.3 Gasoline On-road

Figure 5-21. Port Angeles, on-road gasoline, cancer.
PMI risk = 86 per million



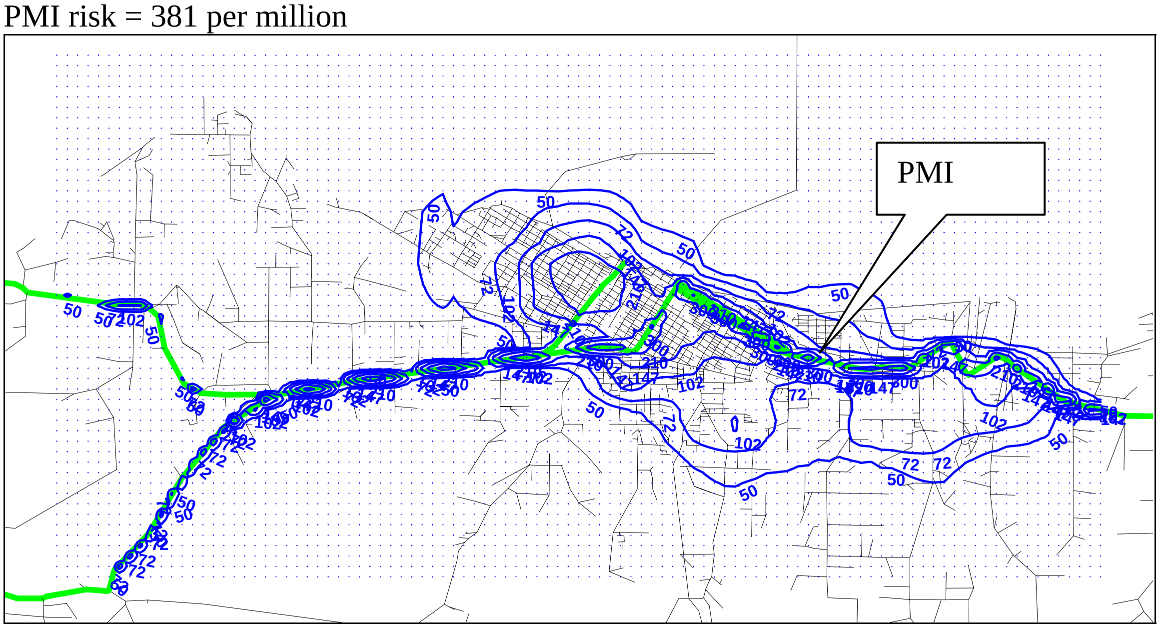
5.4.2.2.4 Wood Stoves and Fireplaces

Figure 5-22. Port Angeles, wood stoves, cancer.
PMI risk = 269 per million



5.4.2.2.5 Total Cancer Risk

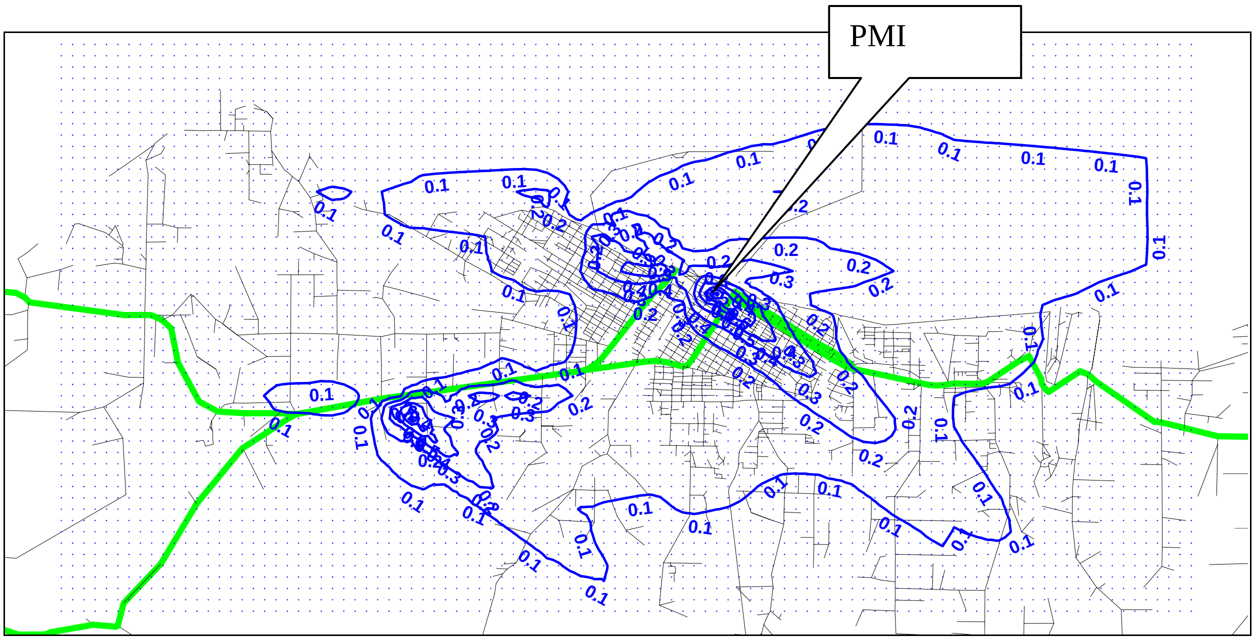
Figure 5-23. Port Angeles, all sources, cancer.
PMI risk = 381 per million



5.4.2.3 Chronic Non-cancer

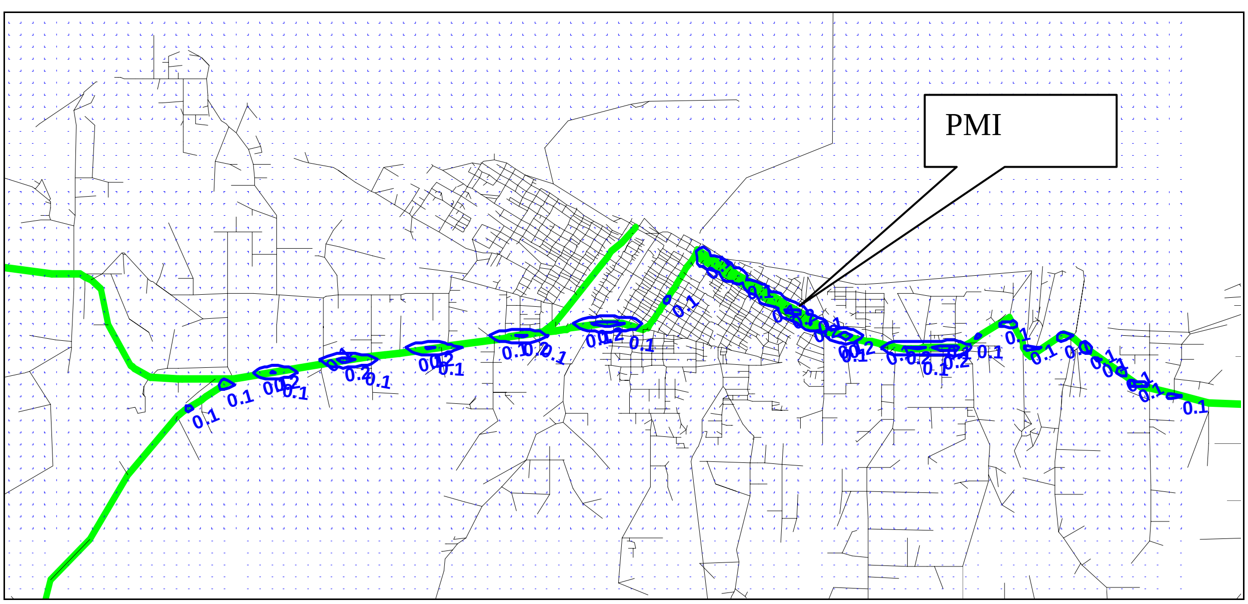
5.4.2.3.1 Point Source (Commerical)

Figure 5-24. Port Angeles, commercial, chronic non-cancer HHI.
PMI risk = 0.83



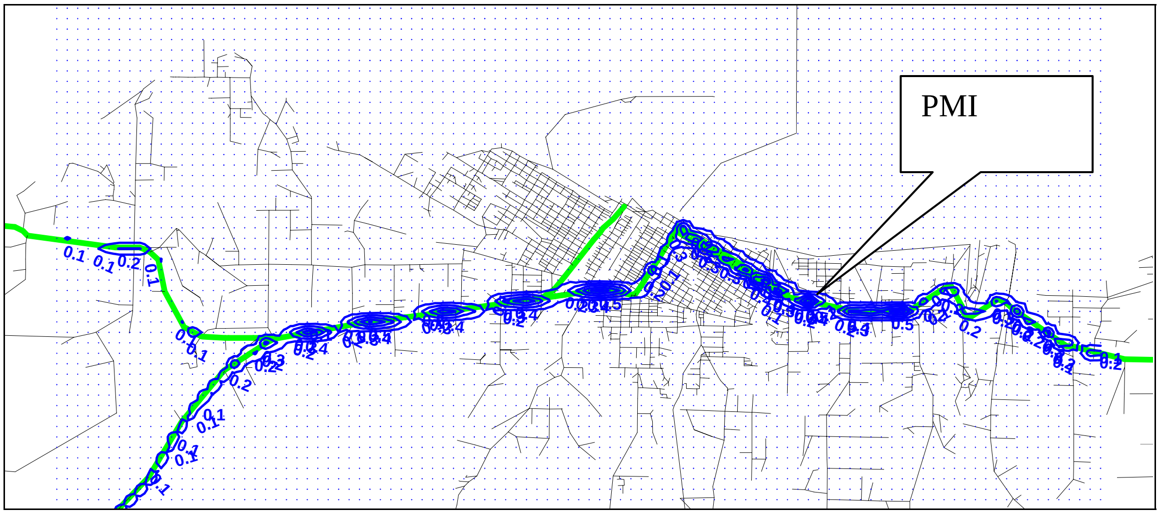
5.4.2.3.2 Diesel On-road

Figure 5-25. Port Angeles, on-road diesel, chronic non-cancer HHI.
PMI risk = 0.27



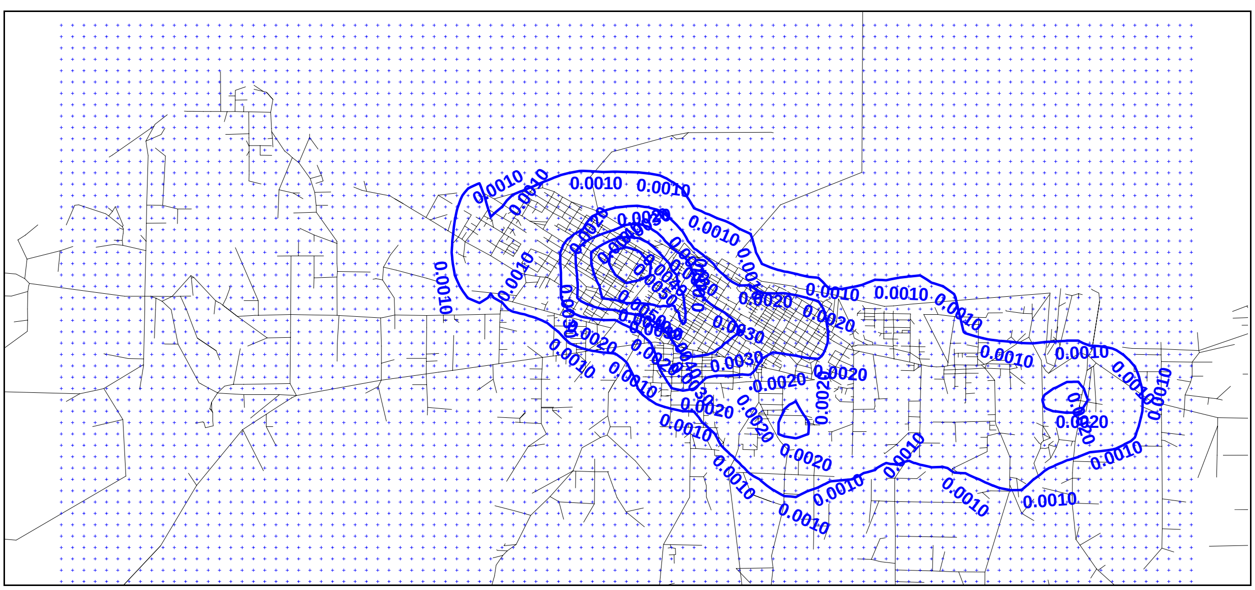
5.4.2.3.3 Gasoline On-road

Figure 5-26. Port Angeles, on-road gasoline, chronic non-cancer HHI.
PMI risk = 0.59



5.4.2.3.4 Wood Stoves and Fireplaces

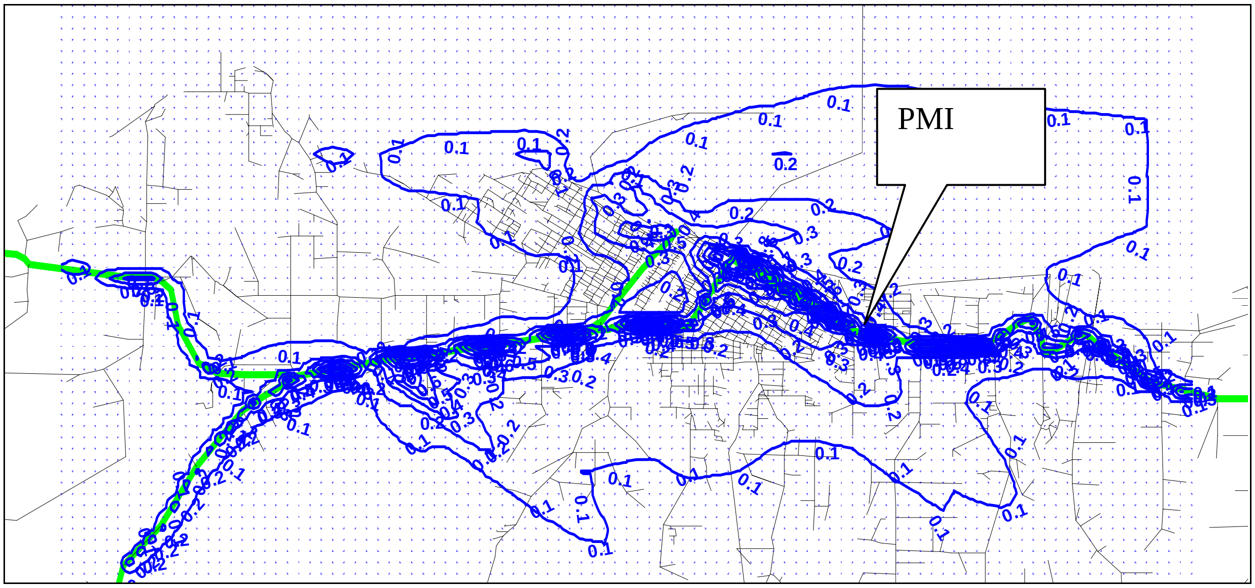
Figure 5-27. Port Angeles, wood stoves, chronic non-cancer HHI.
PMI risk = 0.0057



5.4.2.3.5 Total Chronic Risk

Figure 5-28. Port Angeles, all sources, chronic non-cancer HHI.

PMI risk = 1.05



5.4.3 Aberdeen

5.4.3.1 Summary

Figure 5-29. Aberdeen study area.

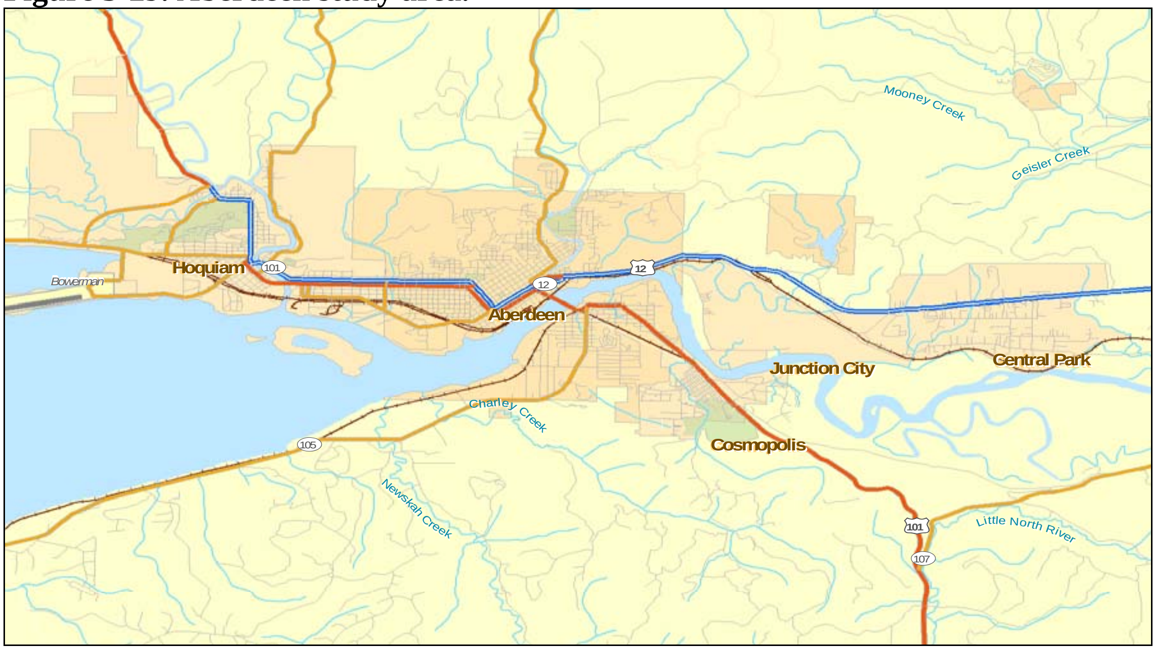


Figure 5-30. Analysis grid and locations of commercial sources. Source locations are indicated by circled X's.

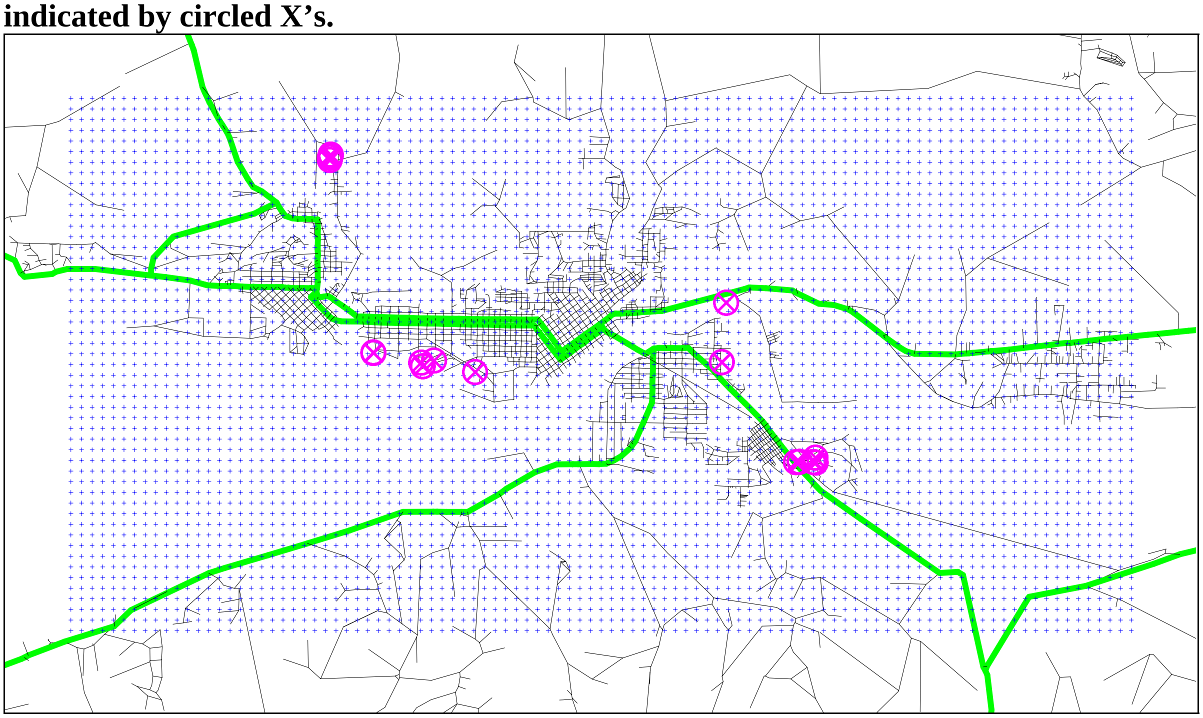


Figure 5-31. Locations of non-commercial sources.
Small magenta squares are locations of on-road freeway, artery, collector and local road sources. (Note that in Aberdeen there are no freeways) Green squares are the boundaries of local road area sources. Blue squares are locations of wood stove sources.

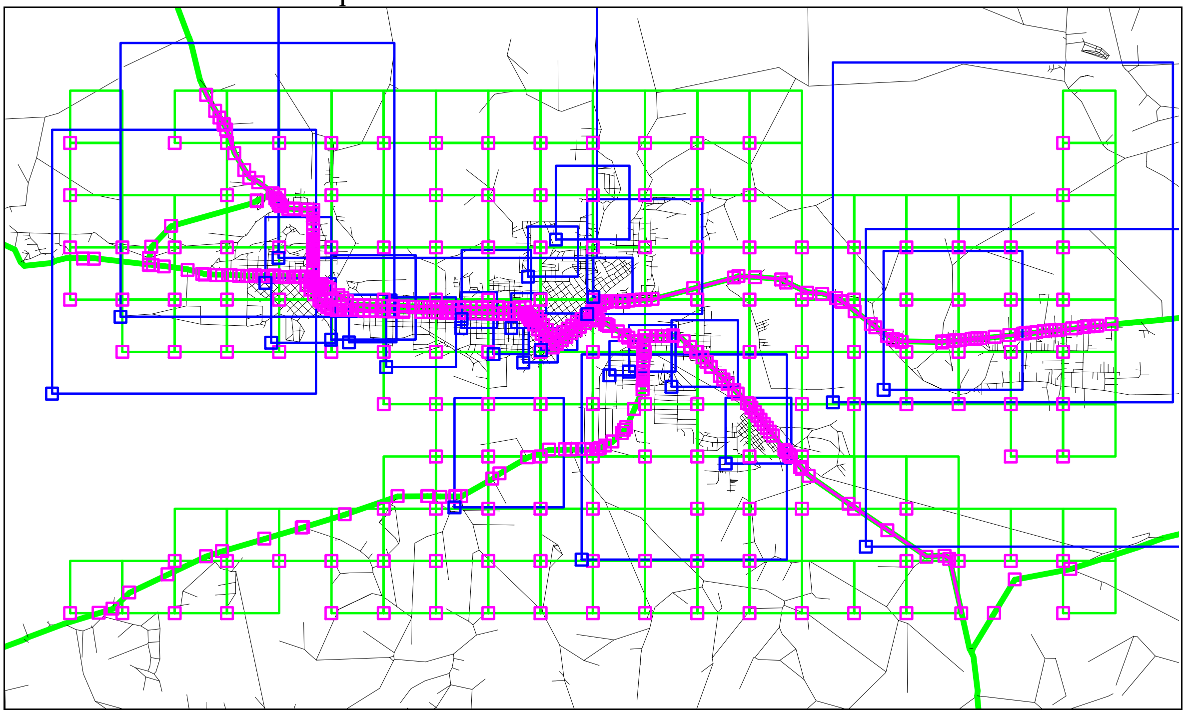
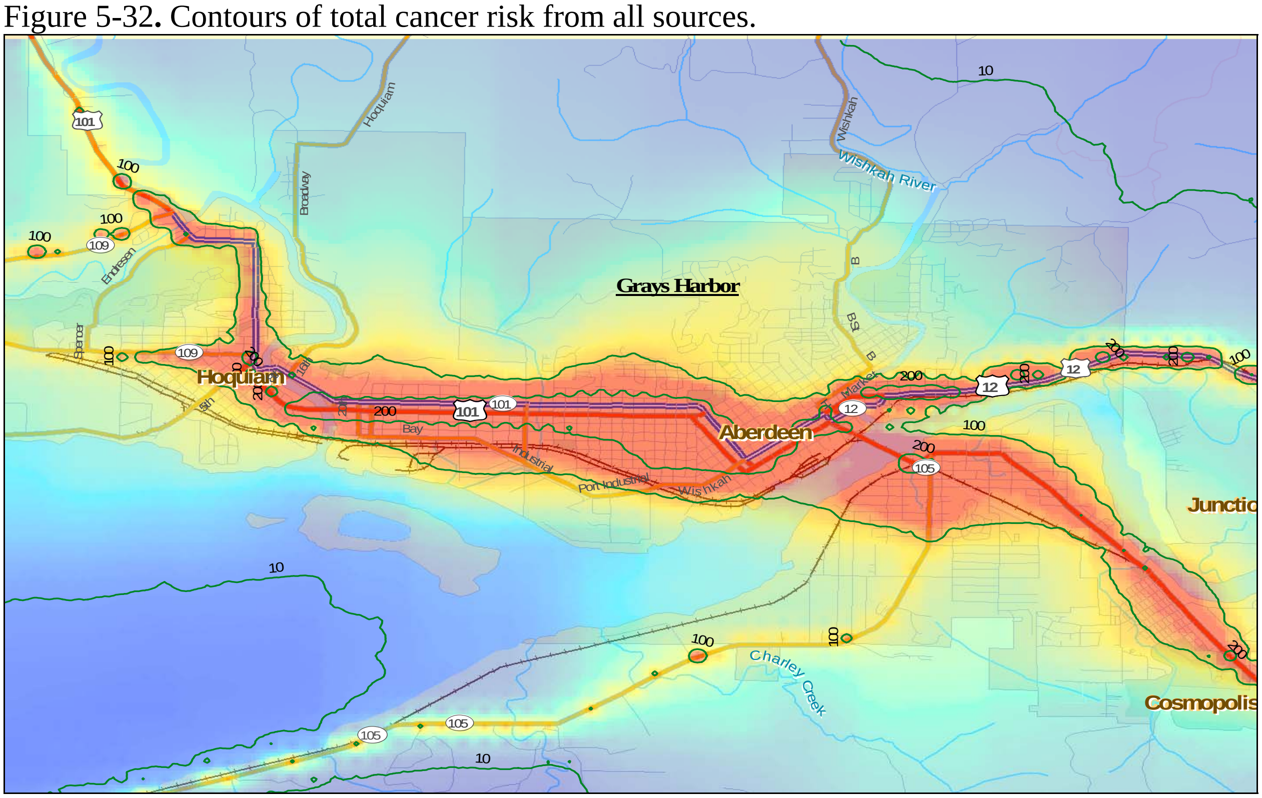


Figure 5-32**.** Contours of total cancer risk from all sources.



5.4.3.2 Cancer

5.4.3.2.1 Point Source (Commercial)

Table 5-22. Commercial sources included in this analysis.

Facility	*Stack*	*UTME*	*UTMN*
WEYERHAEUSER - COSMOPOLIS	stack 84831	441746	5200169
WESTPORT SHIPYARD - HOQUIAM	stack 12393	434608	5202035
GRAYS HARBOR PAPER LP	stack 1903	433704	5202227
WEYERHAEUSER - COSMOPOLIS	stack 84830	441677	5200165
GRAYS HARBOR PAPER LP	stack 1906	433708	5202215
HARPO INVESTMENTS	stack 571	435625	5201858
WEYERHAEUSER - COSMOPOLIS	stack 84829	442045	5200249
OCEAN SPRAY CRANBERRIES INC	stack 61	424043	5194957
HOQUIAM PLYWOOD CO INC	stack 782	432885	5205890
LAKESIDE INDUSTRIES - ABERDEEN	stack 641	440361	5203159
PANELTECH INT. LLC	stack 2468	434850	5202073
WEYERHAEUSER - COSMOPOLIS	stack 84825	442051	5200157
HOQUIAM PLYWOOD CO INC	stack 781	432906	5205929
WESTPORT SHIPYARD - HOQUIAM	stack 12391	434637	5201966
WEYERHAEUSER - COSMOPOLIS	stack 84824	442005	5200168
HOQUIAM PLYWOOD CO INC	stack 783	432900	5205940
HOQUIAM PLYWOOD CO INC	stack 784	432885	5205837
PACIFIC VENEER	stack 805	440279	5202044
PACIFIC VENEER	stack 804	440279	5202044
OCEAN SPRAY CRANBERRIES INC	stack 64	424043	5194957

Table 5-23. Dominant chemicals contributing to cancer risk, commercial sources.

CAS	POLLUTANT NAME	INHAL	DERM	SOIL	TOTAL
18540299	Chromium, hexavalent	2.62E-05	0.00E+00	0.00E+00	2.62E-05
7440382	Arsenic	5.73E-07	3.82E-06	1.86E-06	6.25E-06
71432	Benzene	1.02E-06	0.00E+00	0.00E+00	1.02E-06

Table 5-24. Emissions of dominant chemicals.
Chromium, hexavalent

Facility	Annual EMS (lbs/yr)
GRAYS HARBOR PAPER LP	60

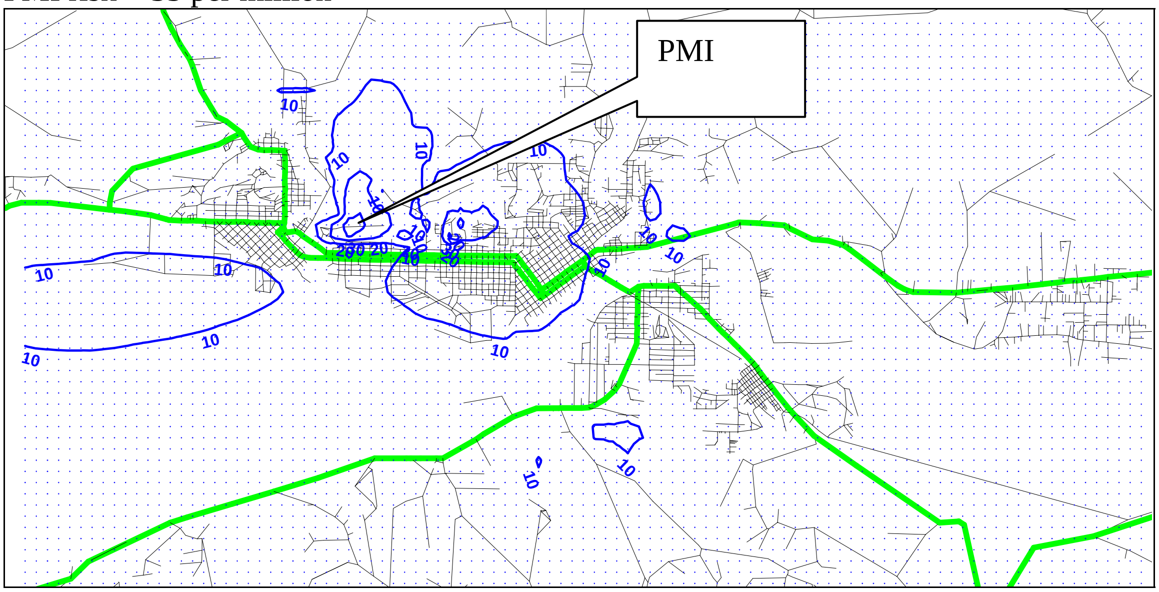
Arsenic

Facility	Annual EMS (lbs/yr)
GRAYS HARBOR PAPER LP	62

Benzene

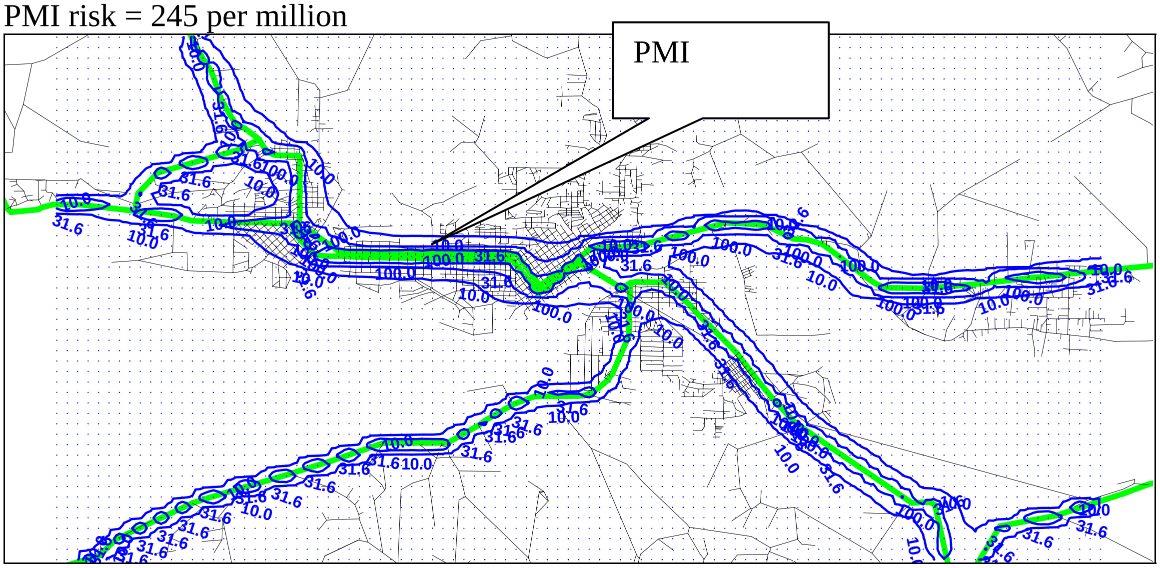
Facility	Annual EMS (lbs/yr)
GRAYS HARBOR PAPER LP	62

Figure 5-33. Aberdeen, commercial, cancer.
PMI risk = 35 per million



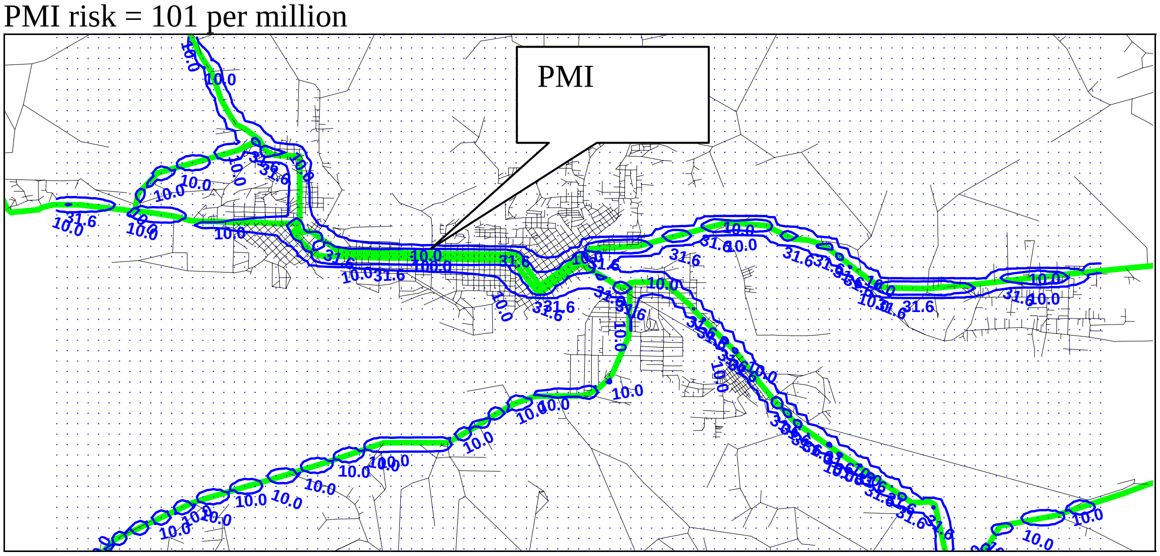
5.4.3.2.2 Diesel On-road

Figure 5-34. Aberdeen, diesel, cancer.
PMI risk = 245 per million



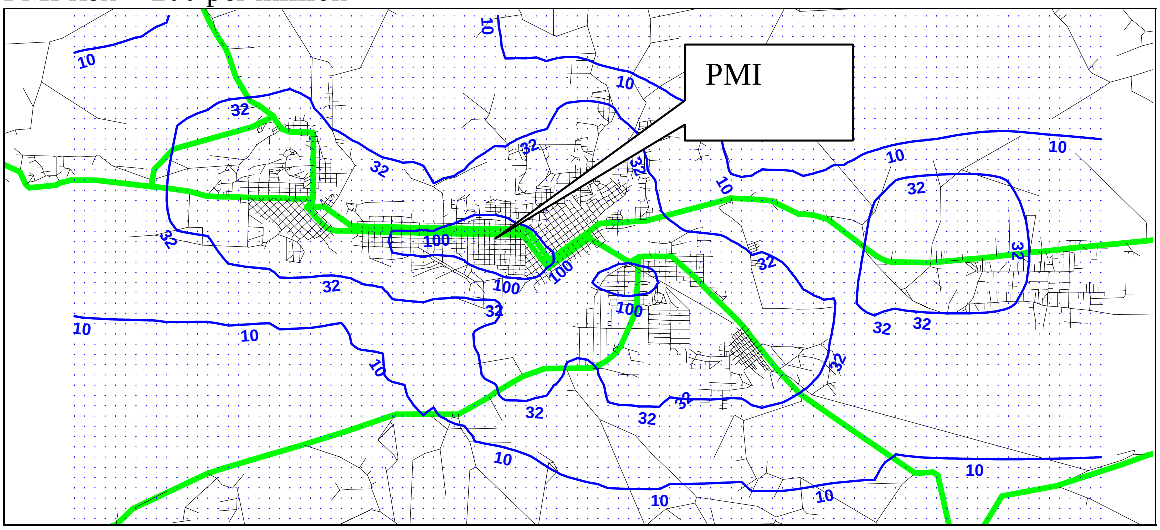
5.4.3.2.3 Gasoline On-road

Figure 5-35. Aberdeen, gasoline, cancer.
PMI risk = 101 per million



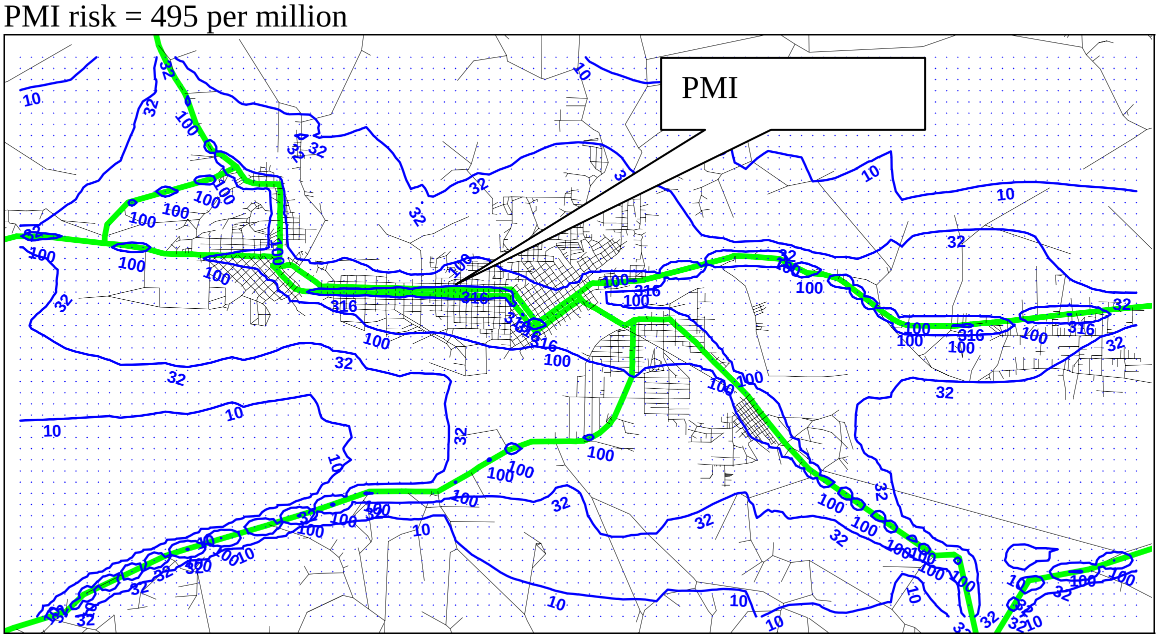
5.4.3.2.4 Wood Stoves and Fireplaces

Figure 5-36. Aberdeen, wood stoves, cancer.
PMI risk = 200 per million



5.4.3.2.5 Total Cancer Risk

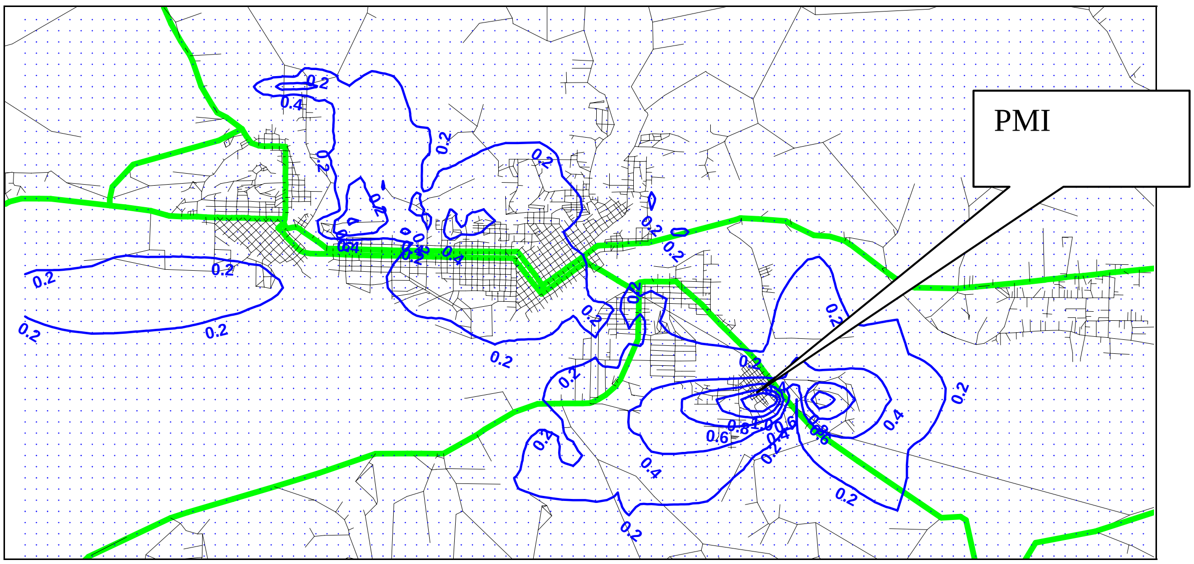
Figure 5-37. Aberdeen, all sources, cancer.
PMI risk = 495 per million



5.4.3.3 Chronic Non-cancer

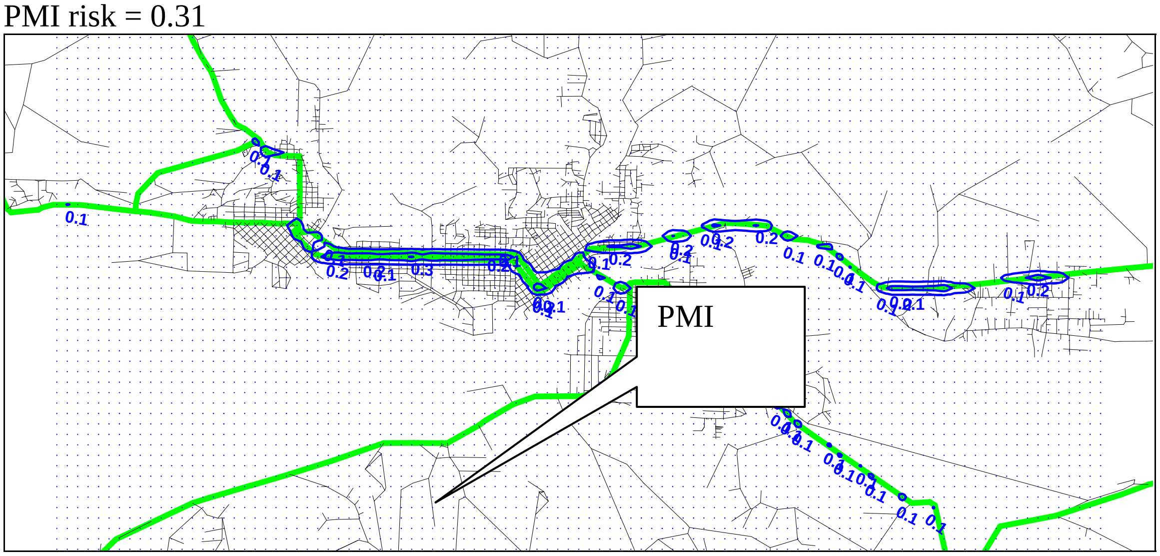
5.4.3.3.1 Point Source (Commerical)

Figure 5-38. Aberdeen , commercial, chronic non-cancer HHI.
PMI risk = 1.36



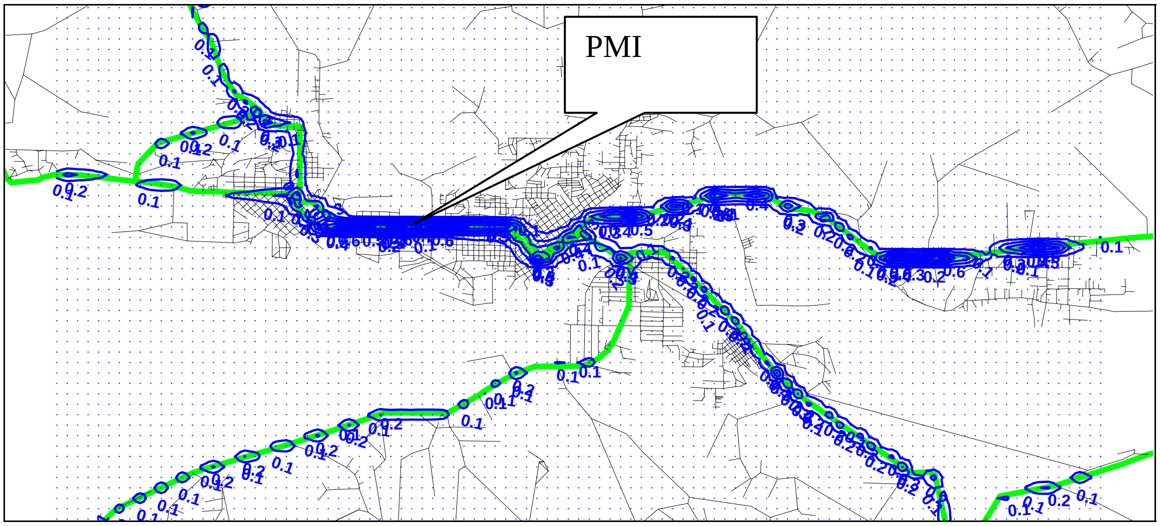
5.4.3.3.2 Diesel On-road

Figure 5-39. Aberdeen, diesel, chronic non-cancer HHI.
PMI risk = 0.31



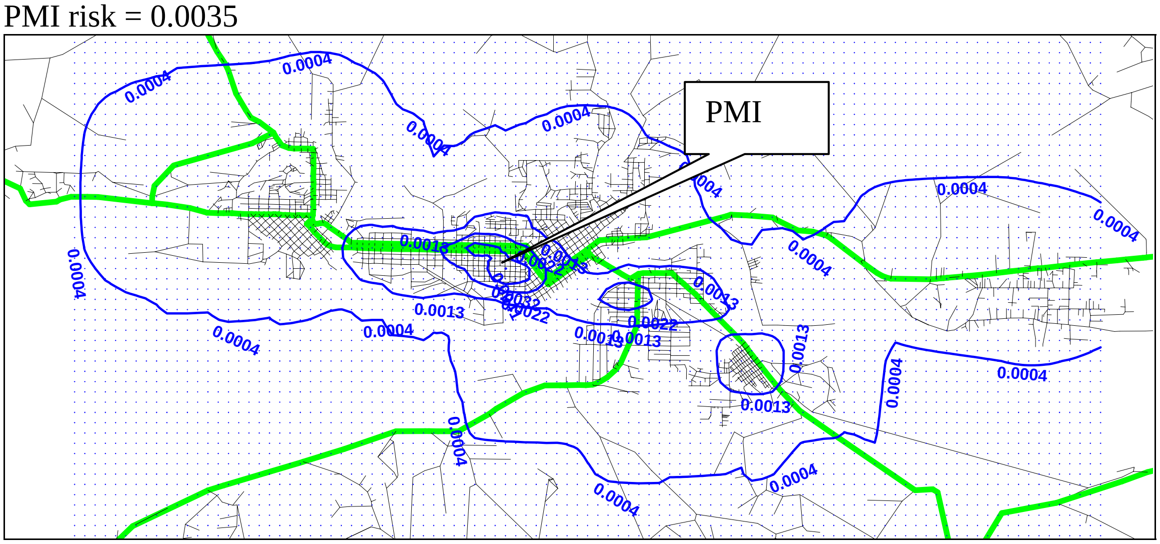
5.4.3.3.3 Gasoline On-road

Figure 5-40. Aberdeen, gasoline, chronic non-cancer HHI.
PMI risk = 0.70



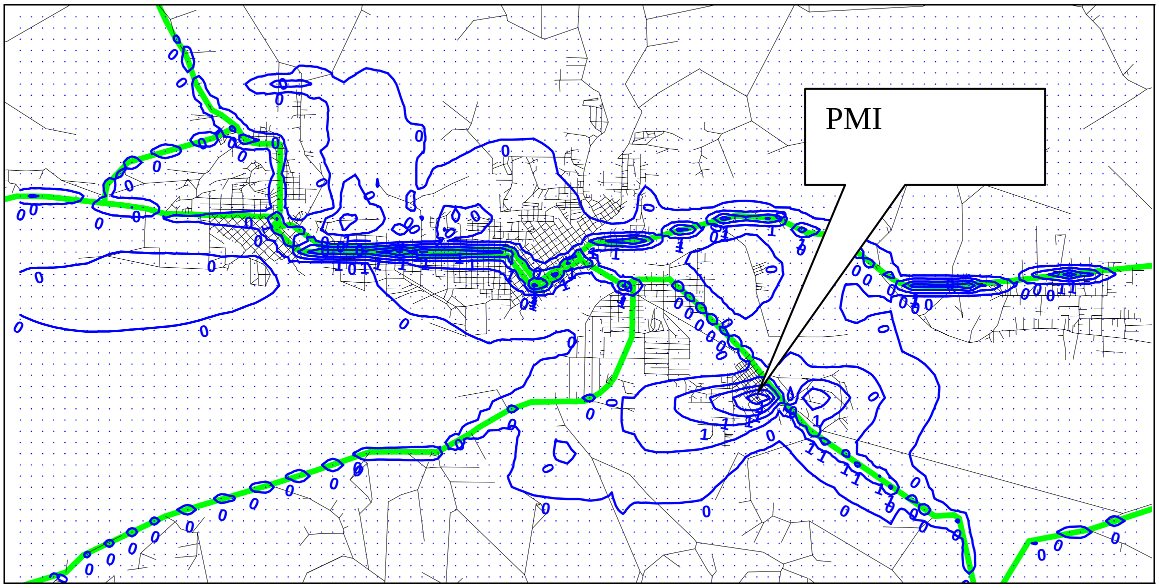
5.4.3.3.4 Wood Stoves and Fireplaces

Figure 5-41. Aberdeen, wood stoves, chronic non-cancer HHI.
PMI risk = 0.0035



5.4.3.3.5 Total Chronic Risk

Figure 5-42. Aberdeen, all sources, chronic non-cancer HHI.
PMI risk = 1.4



5.4.4 Grays Harbor Coastal

5.4.4.1 Summary

Figure 5-43. Grays Harbor study area.

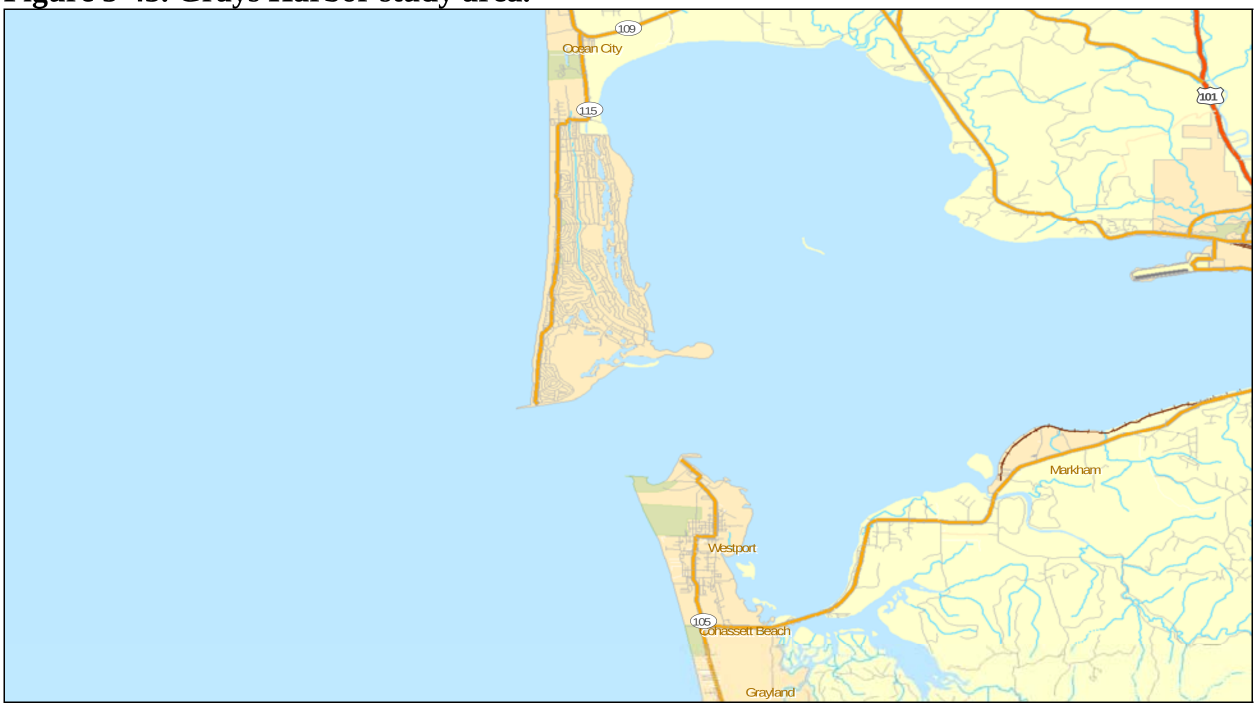


Figure 5-44. Analysis grid and locations of commercial sources. Source locations are indicated by circled X's.

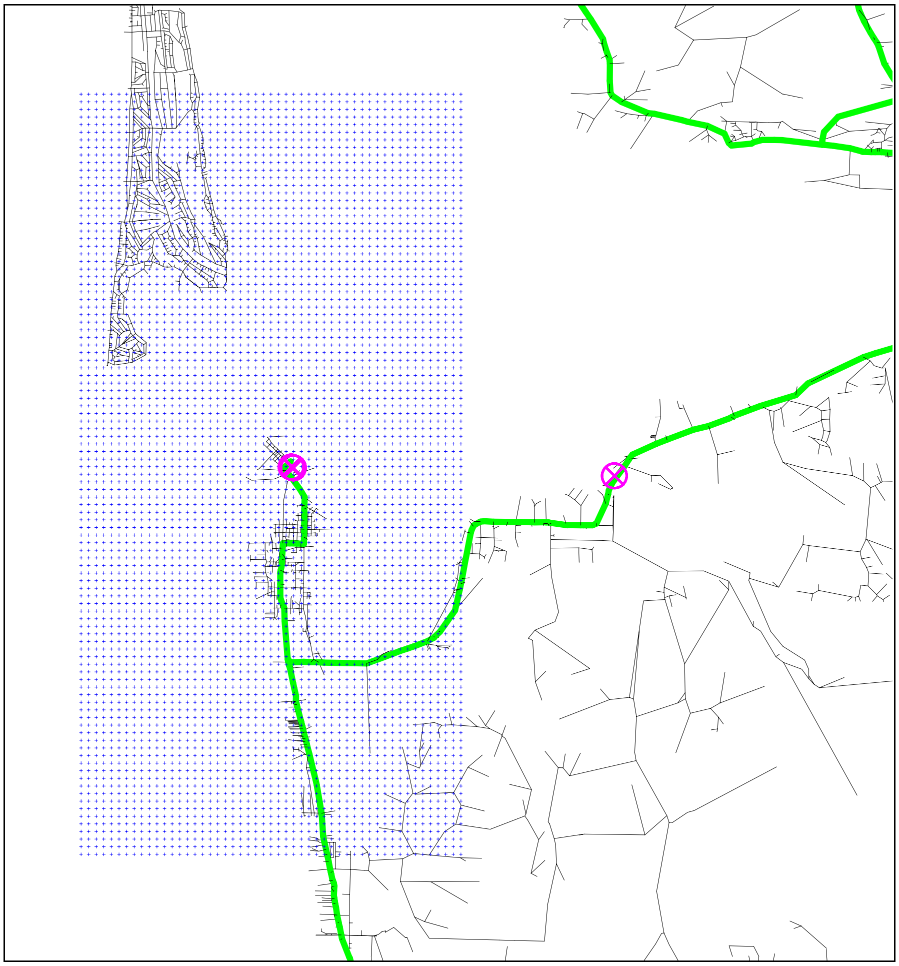


Figure 5-45. Locations of non-commercial sources.
Small magenta squares are locations of on-road freeway, artery, collector and local road sources. (Note that in Grays Harbor there are no freeways or arteries, only collectors and local roads) Green squares are the boundaries of local road area sources. Blue squares are locations of wood stove sources.

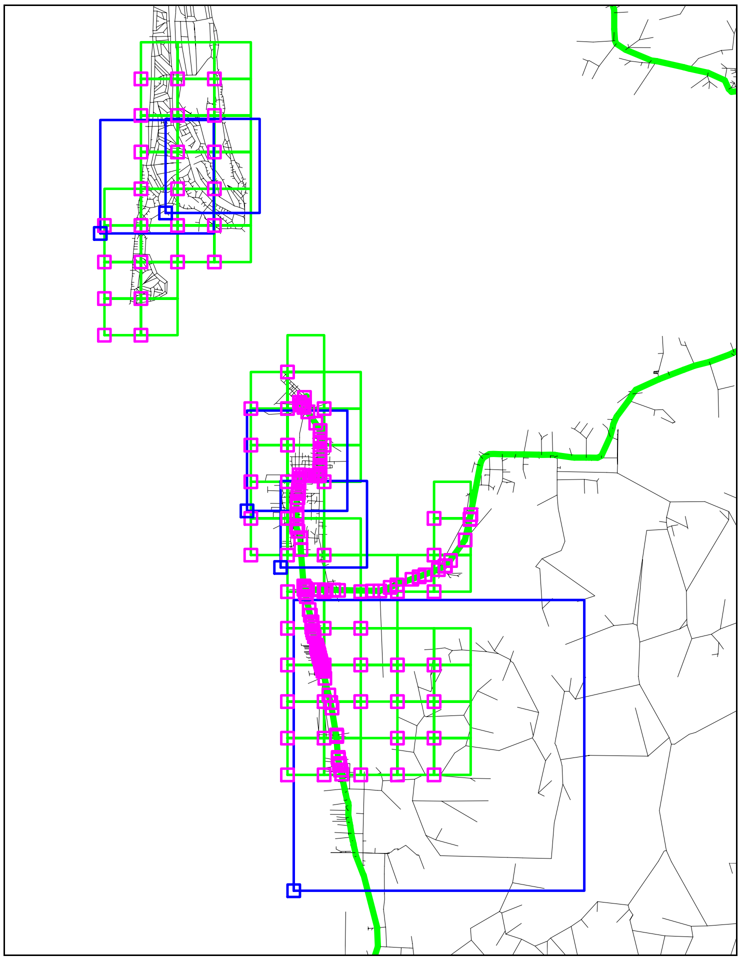
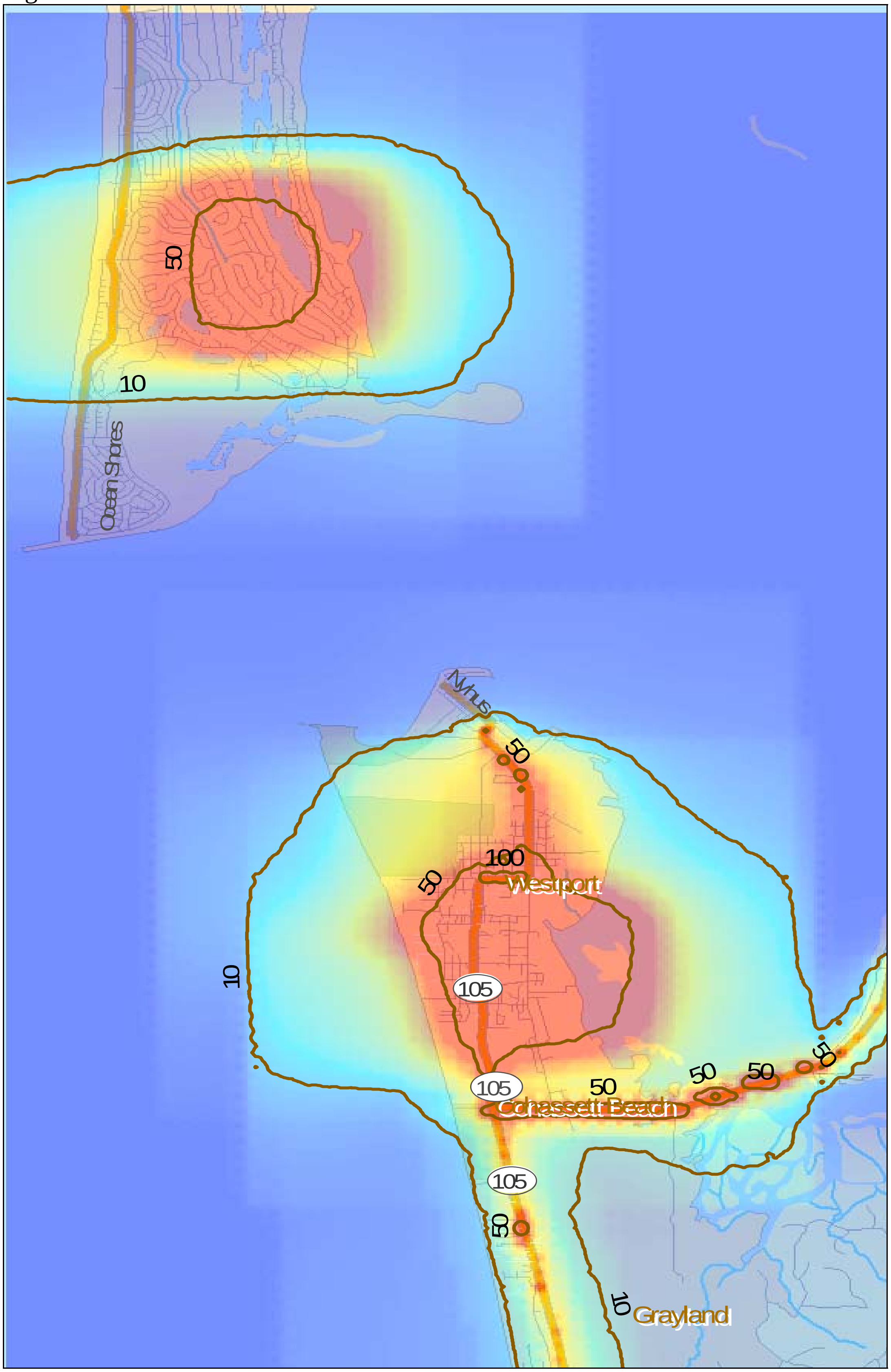


Figure 5-46. Contours of total cancer risk from all sources.



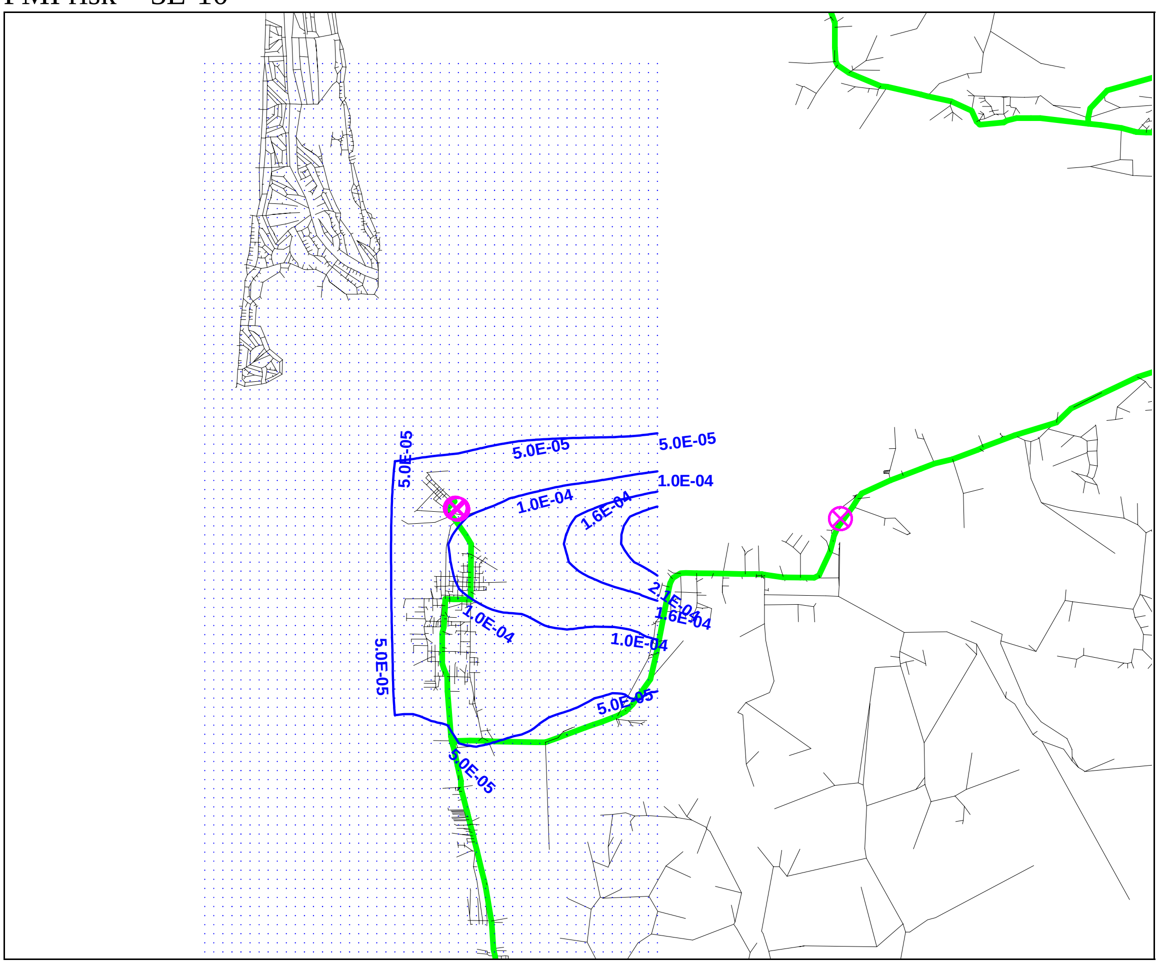
5.4.4.2 Cancer

5.4.4.2.1 Point Source (Commerical)

Table 5-25. Commercial sources included in this analysis.

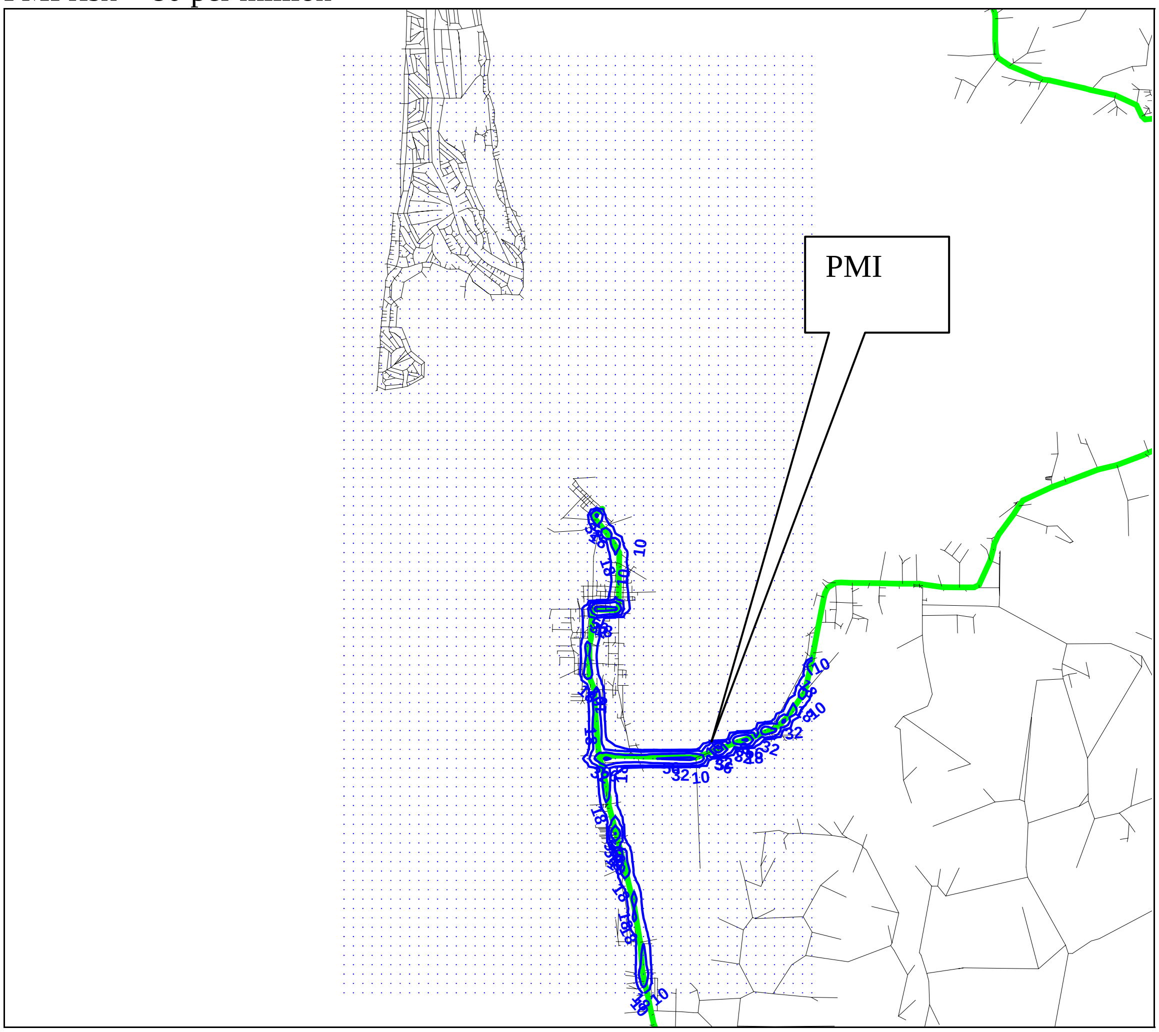
Facility	*Stack*	*UTME*	*UTMN*
		meters	*meters*
WESTPORT SHIPYARD INC	stack 16120	415588	5195165
WESTPORT SHIPYARD INC	stack 1612	415588	5195165
WESTPORT SHIPYARD INC	stack 1611	415538	5195188
OCEAN SPRAY CRANBERRIES INC	stack 64	424043	5194957
OCEAN SPRAY CRANBERRIES INC	stack 61	424043	5194957

Figure 5-47. Grays Harbor, commercial, cancer.
PMI risk = 3E-10



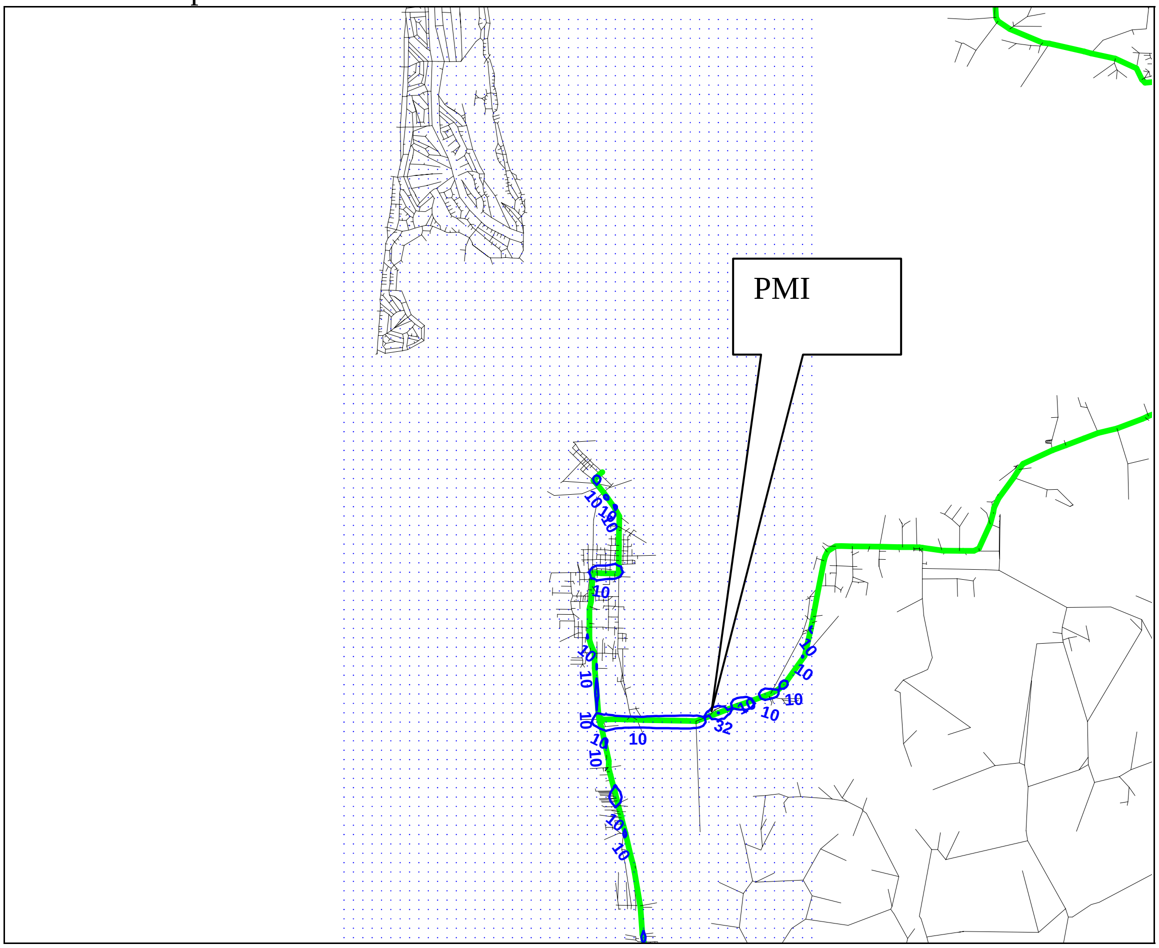
5.4.4.2.2 Diesel On-road

Figure 5-48. Grays Harbor, on-road diesel, cancer.
PMI risk = 80 per million



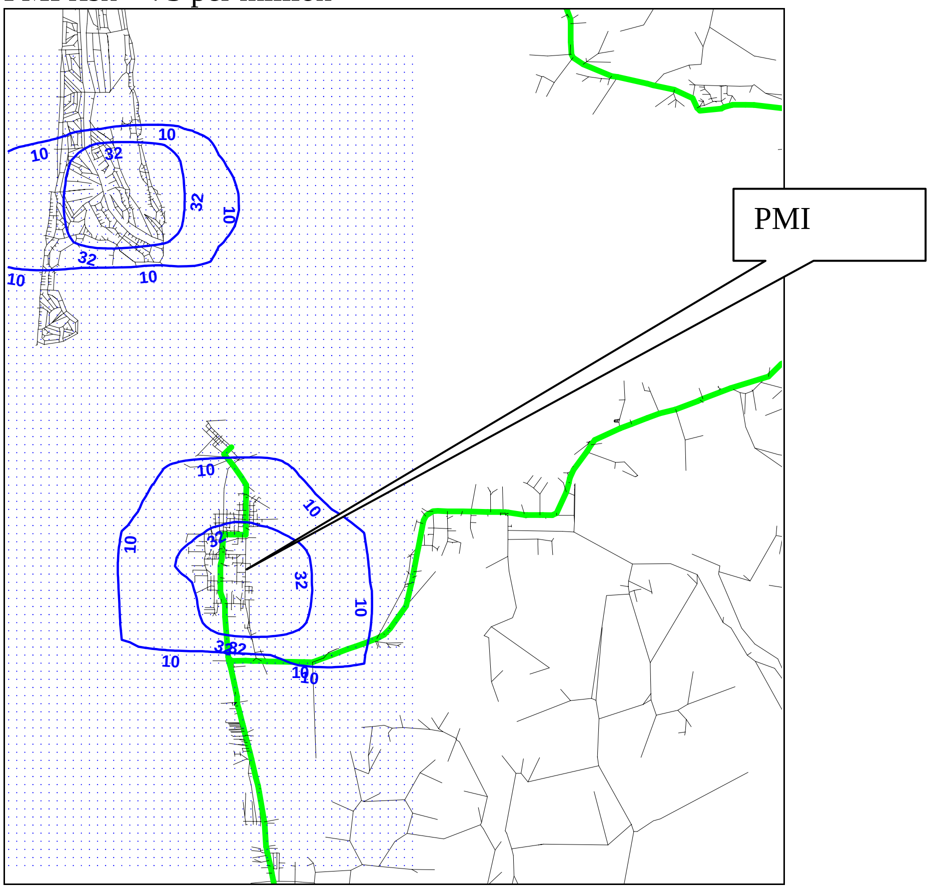
5.4.4.2.3 Gasoline On-road

Figure 5-49. Grays Harbor, on-road gasoline, cancer.
PMI risk = 33 per million



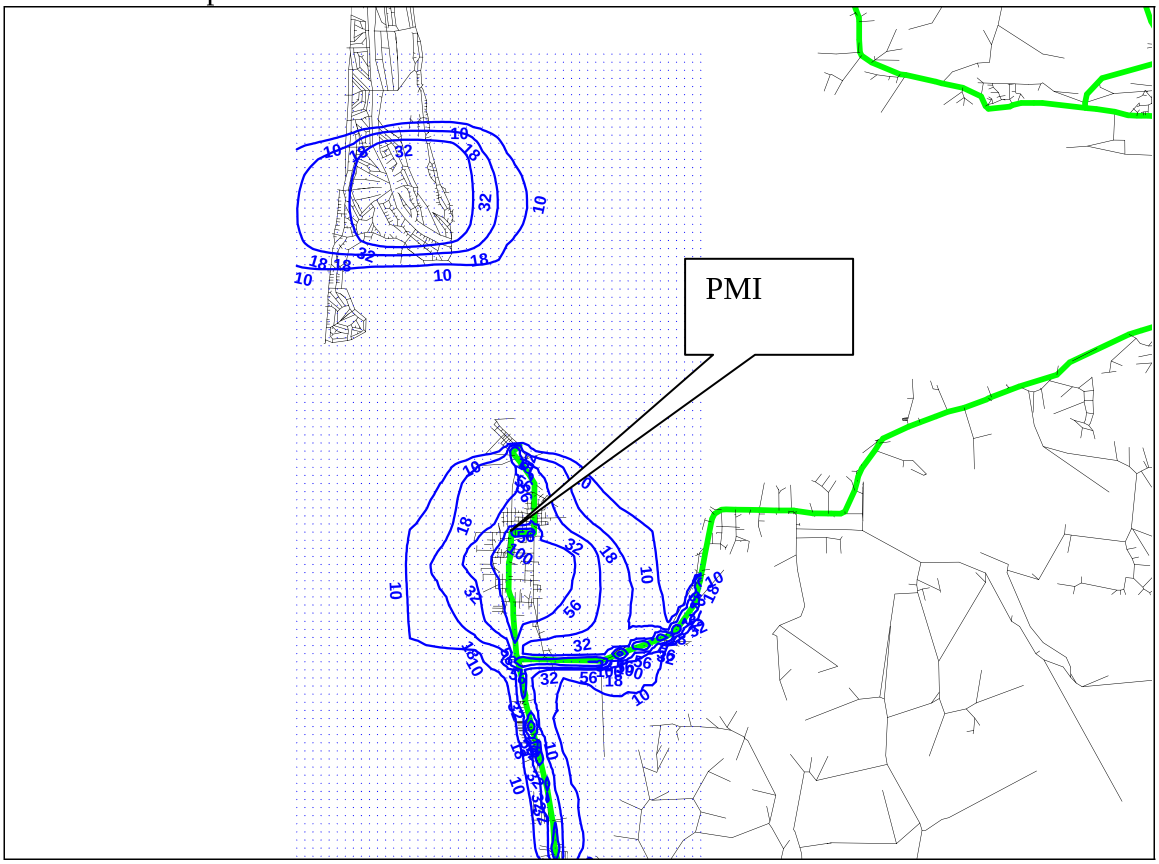
5.4.4.2.4 Wood Stoves and Fireplaces

Figure 5-50. Grays Harbor, wood stoves, cancer.
PMI risk = 73 per million



5.4.4.2.5 Total Cancer Risk

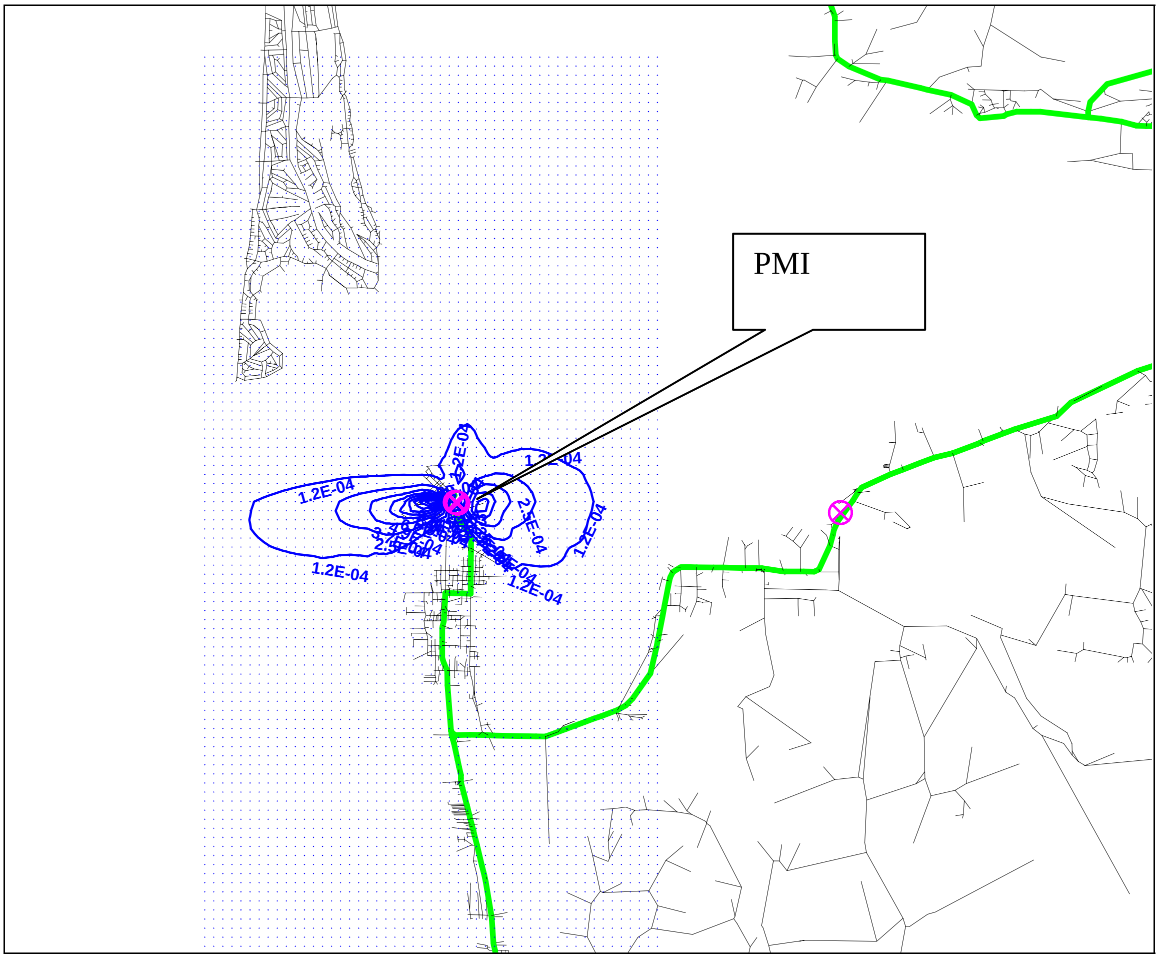
Figure 5-51. Grays Harbor, all sources, cancer.
PMI risk = 137 per million



5.4.4.3 Chronic Non-cancer

5.4.4.3.1 Point Source (Commerical)

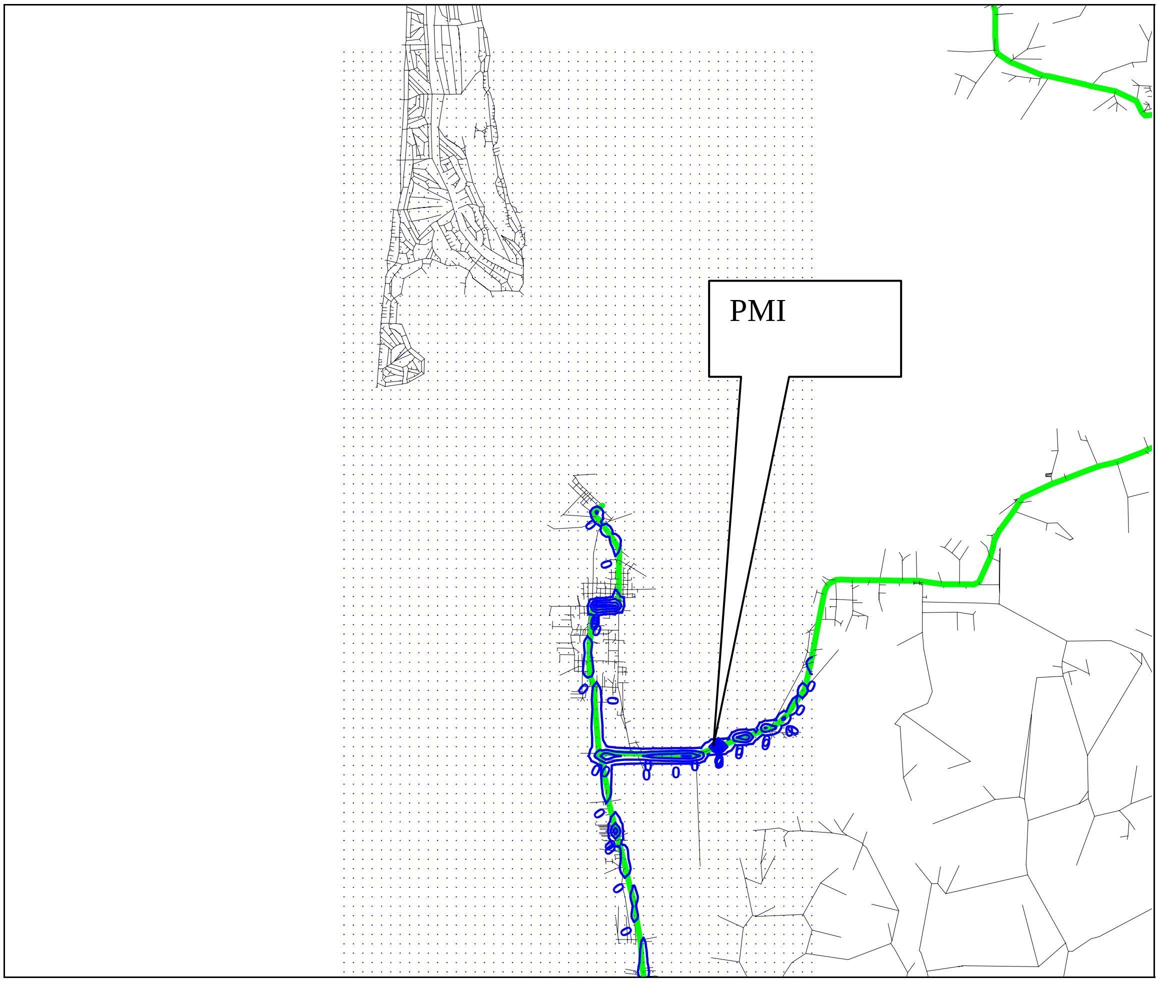
Figure 5-52. Grays Harbor, commercial, chronic non-cancer HHI.
PMI risk = <0.1



5.4.4.3.2 Diesel On-road

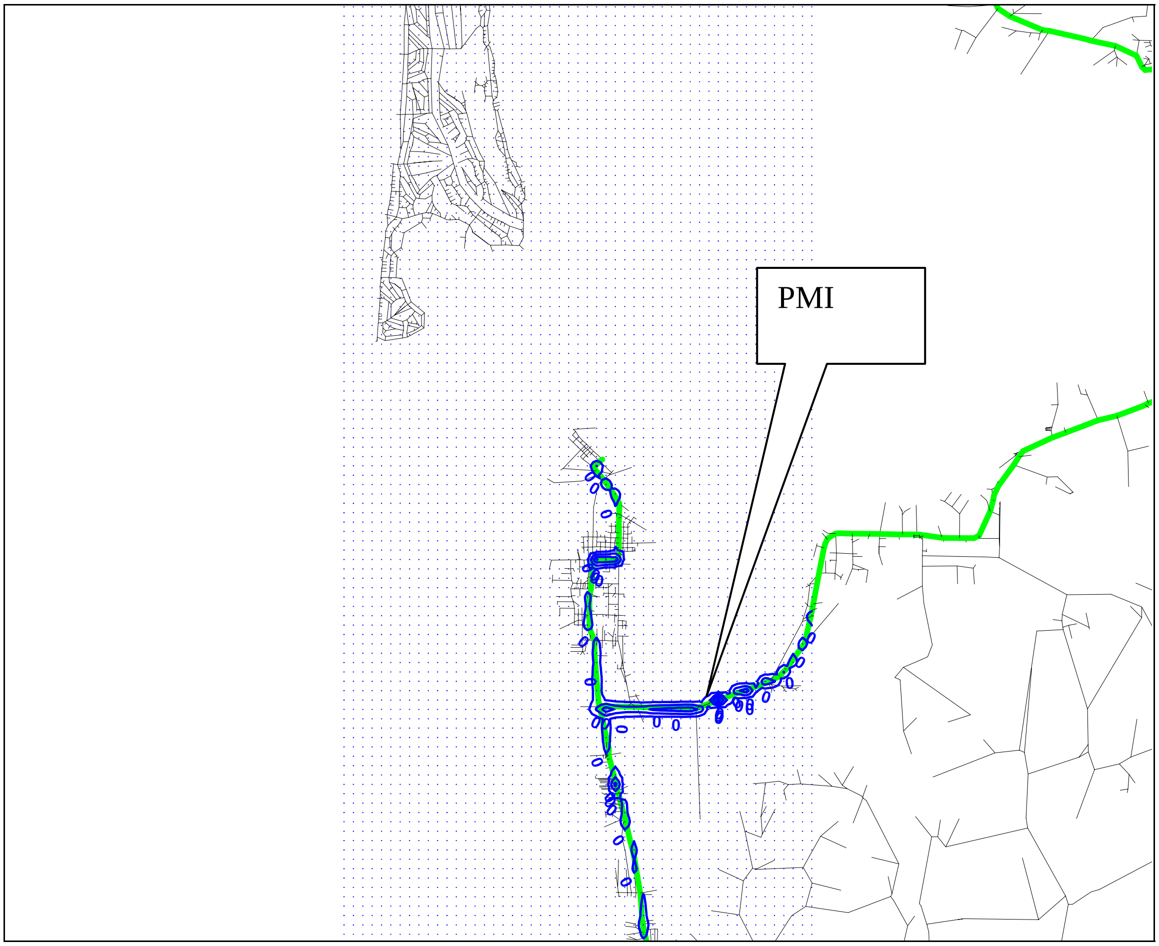
Figure 5-53. Grays Harbor, on-road diesel, chronic non-cancer HHI.

PMI risk = 0.10



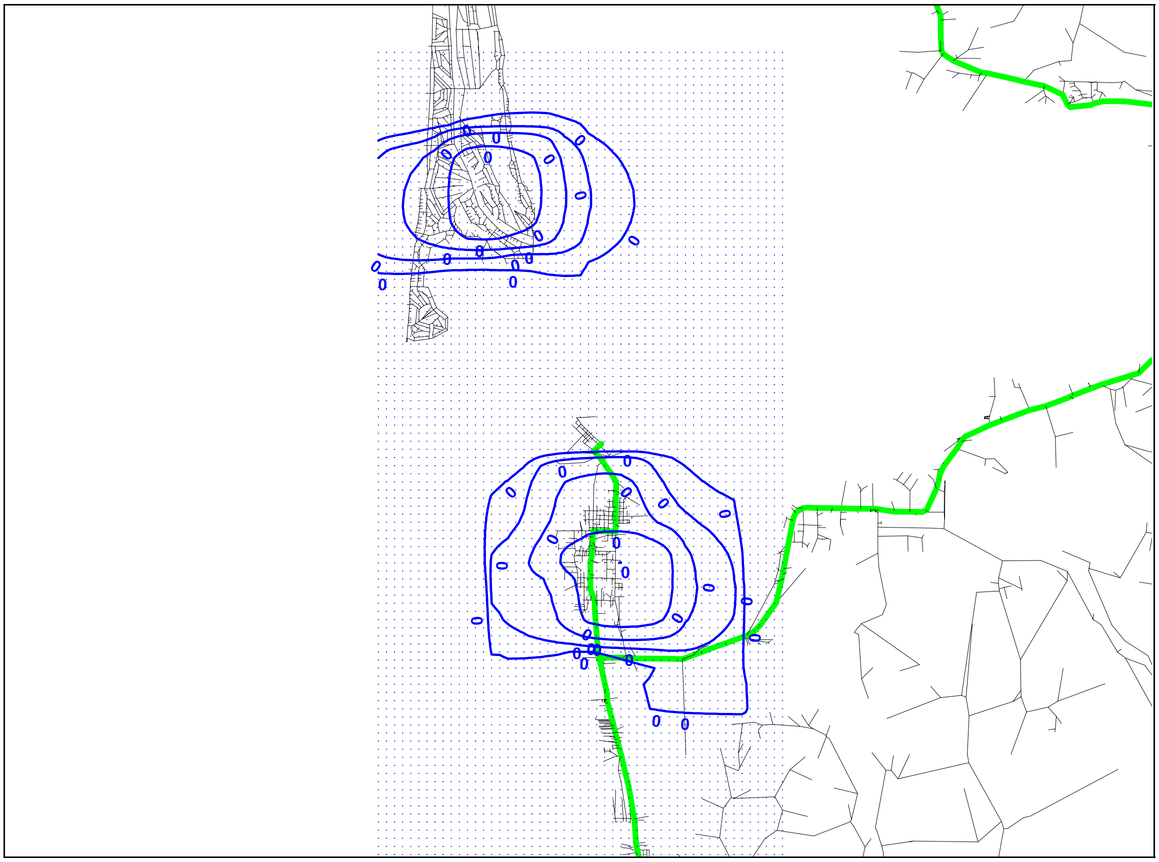
5.4.4.3.3 Gasoline On-road

Figure 5-54. Grays Harbor, on-road gasoline, chronic non-cancer HHI.
PMI risk = 0.23



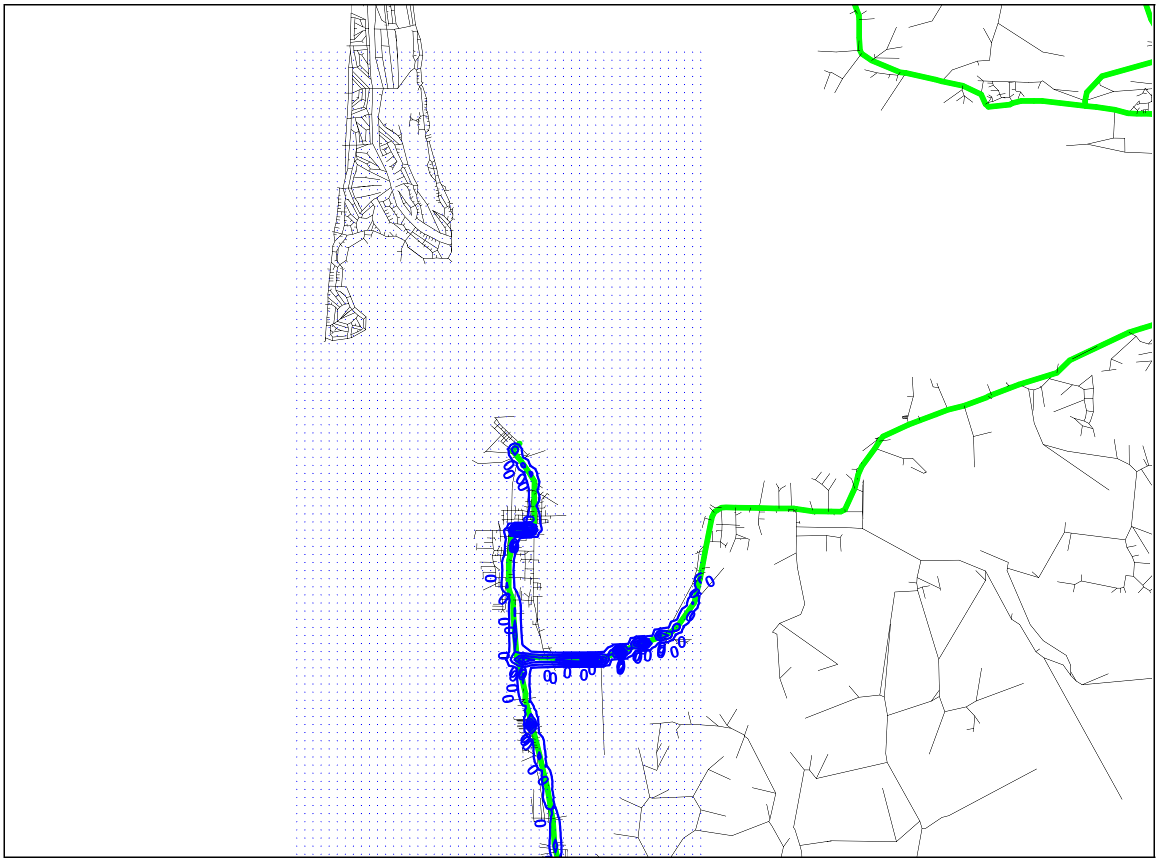
5.4.4.3.4 Wood Stoves and Fireplaces

Figure 5-55. Grays Harbor, wood stoves, chronic non-cancer HHI.
PMI risk = 0.0015



5.4.4.3.5 Total Chronic Risk

Figure 5-56. Grays Harbor, all sources, chronic non-cancer HHI.
PMI risk = 0.33



5.4.5 Raymond

5.4.5.1 Summary

Figure 5-57. Raymond study area.

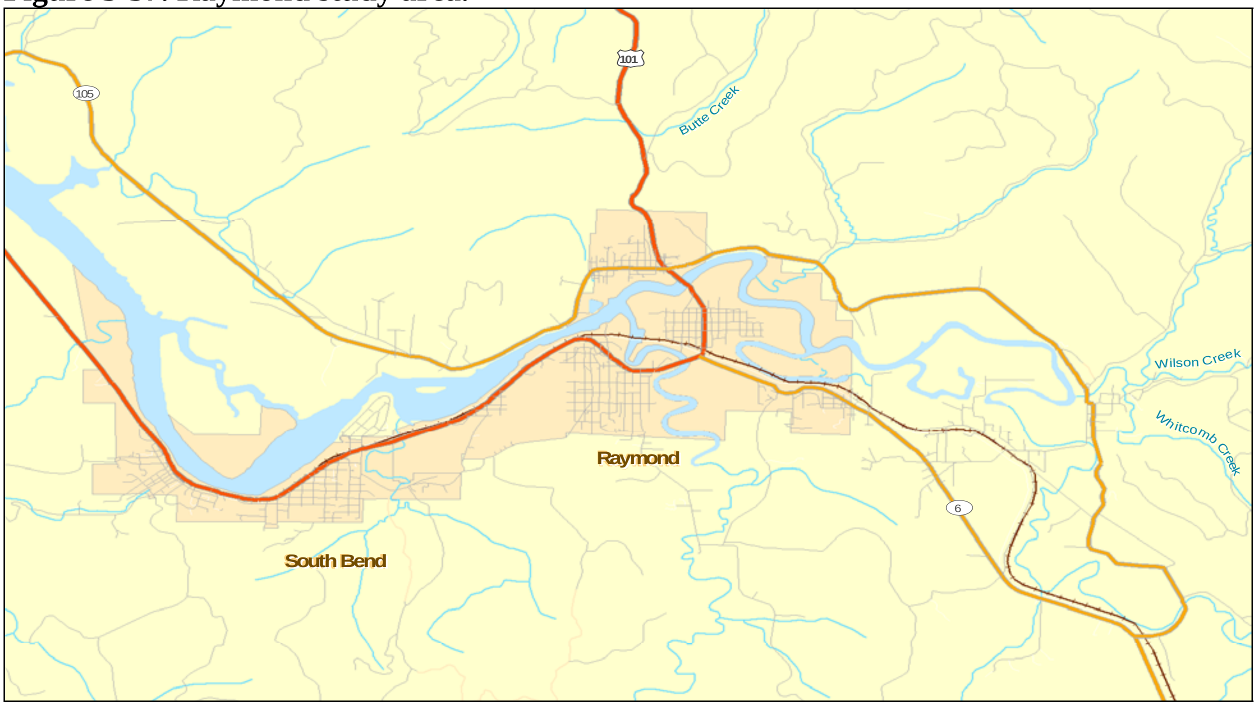


Figure 5-58. Analysis grid and locations of commercial sources. Source locations are indicated by circled X's.

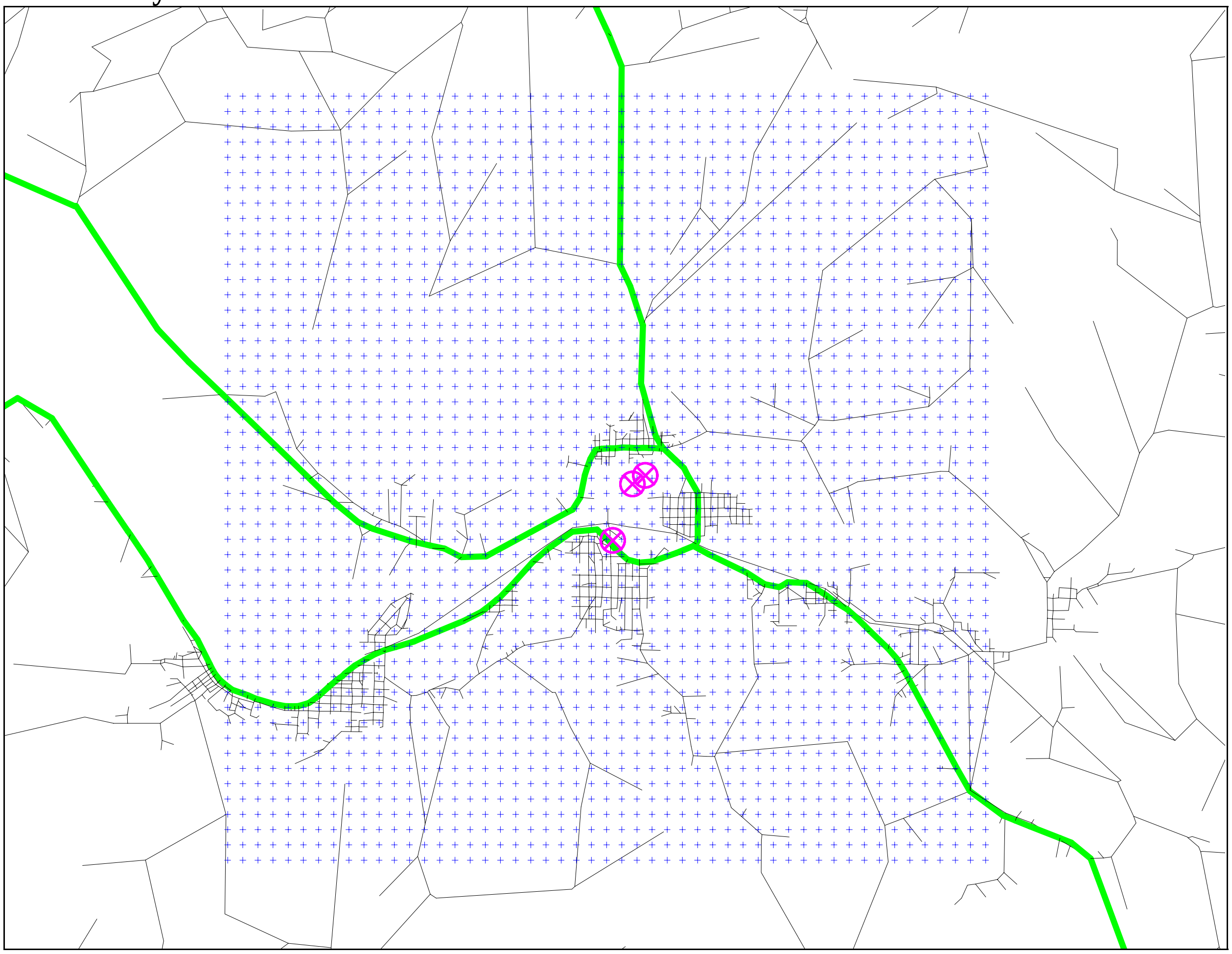


Figure 5-59. Locations of non-commercial sources.
Small magenta squares are locations of on-road freeway, artery, collector and local road sources. (Note that in Raymond there are no freeways) Green squares are the boundaries of local road area sources. Blue squares are locations of wood stove sources.

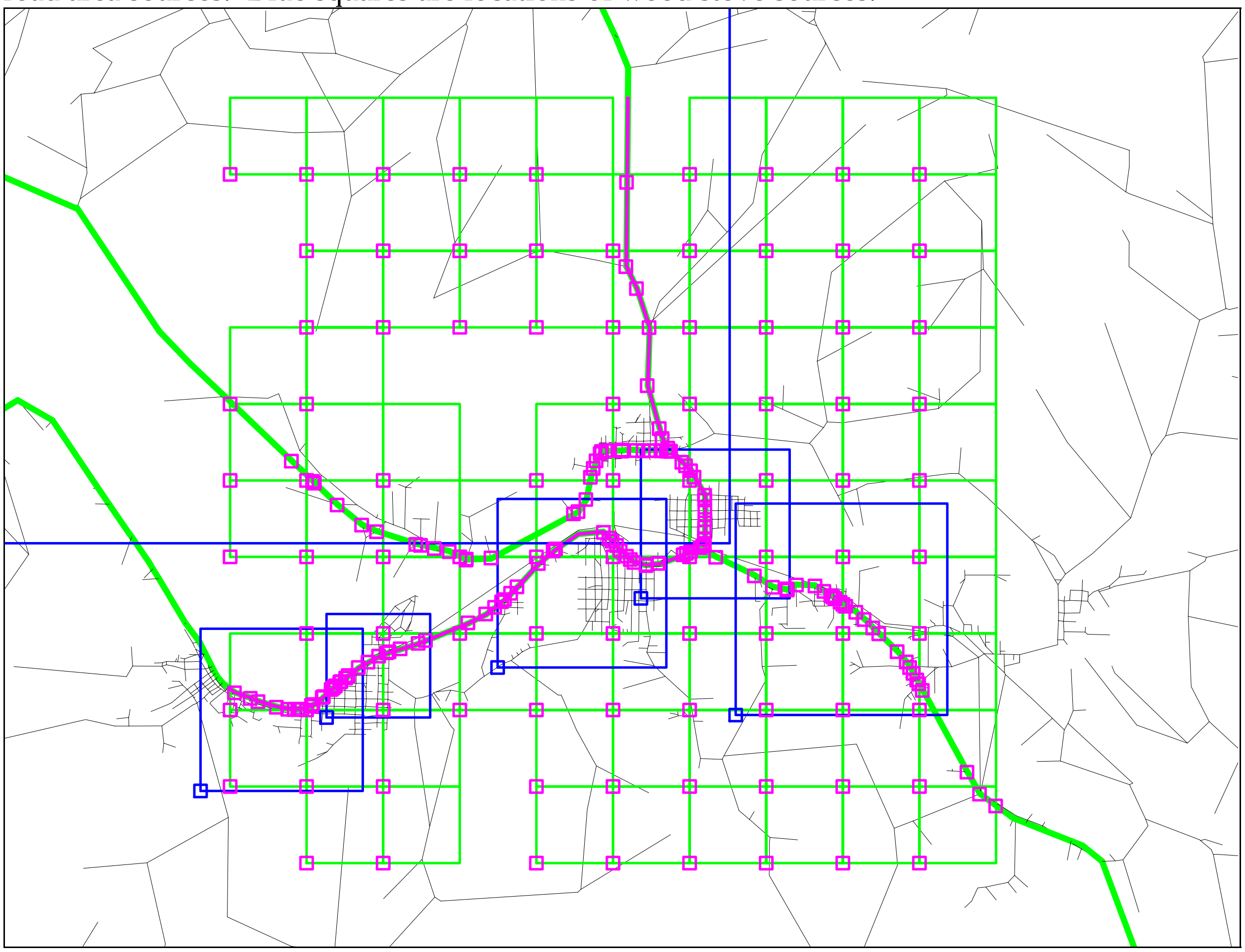
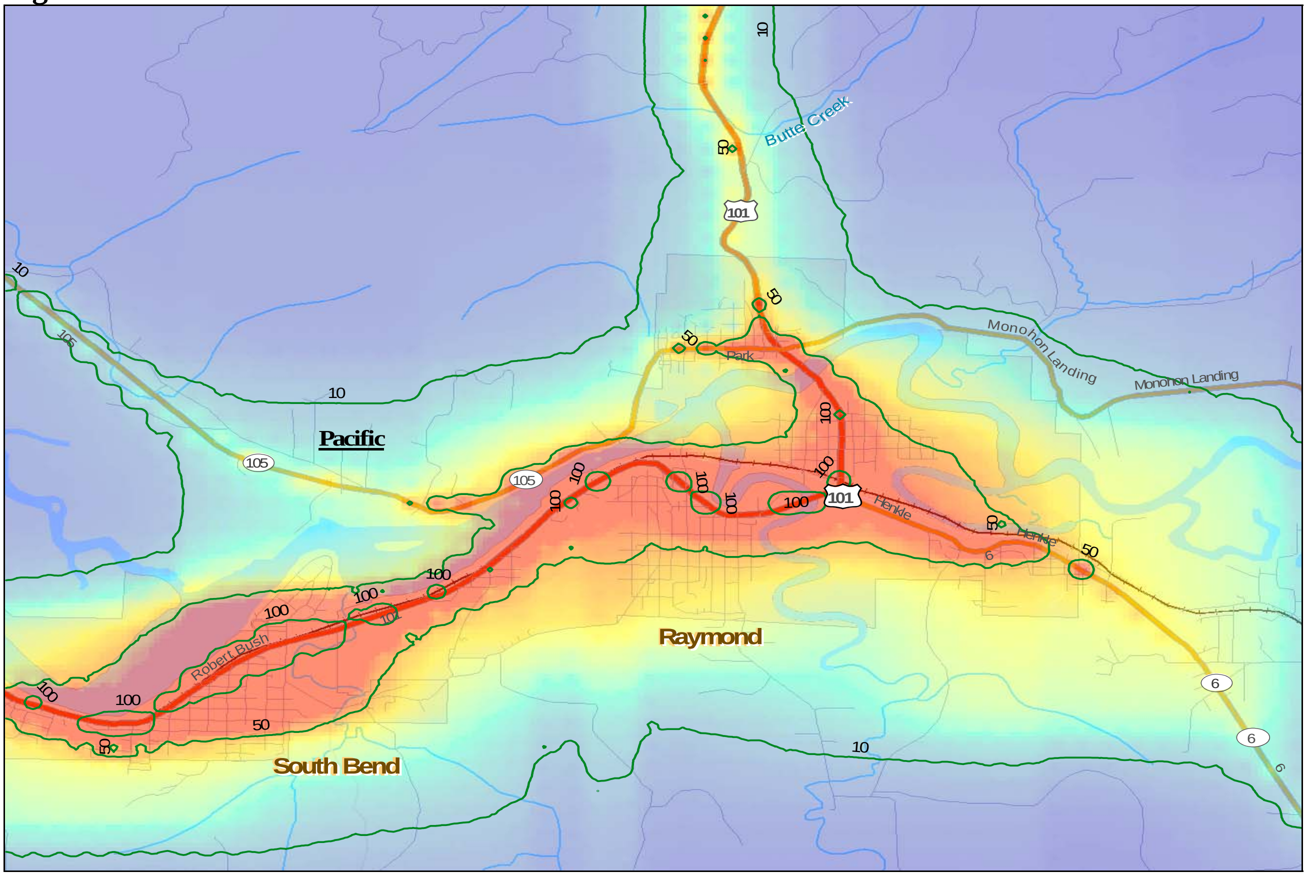


Figure 5-60. Contours of total cancer risk from all sources.



5.4.5.2 Cancer

5.4.5.2.1 Point Source (Commerical)

Table 5-26. Commercial sources included in this analysis.

Facility	***Stack***	***UTME***	***UTMN***
		meters	***meters***
WEYERHAEUSER - RAYMOND	stack 8213	443342	5170923
WEYERHAEUSER - RAYMOND	stack 8211	443512	5171035
SEAPORT LUMBER COMPANY INC - RAYMOND	stack 12551	443082	5170184

Table 5-27. Emissions of dominant chemicals by facility.

CAS	POLLUTANT NAME	INHAL	DERM	SOIL	TOTAL
18540299	Chromium, hexavalent	1.59E-06	0.00E+00	0.00E+00	1.59E-06
7440382	Arsenic	1.01E-07	6.74E-07	3.28E-07	1.10E-06

Table 5-28. Emissions of dominant chemicals.

Chromium, hexavalent

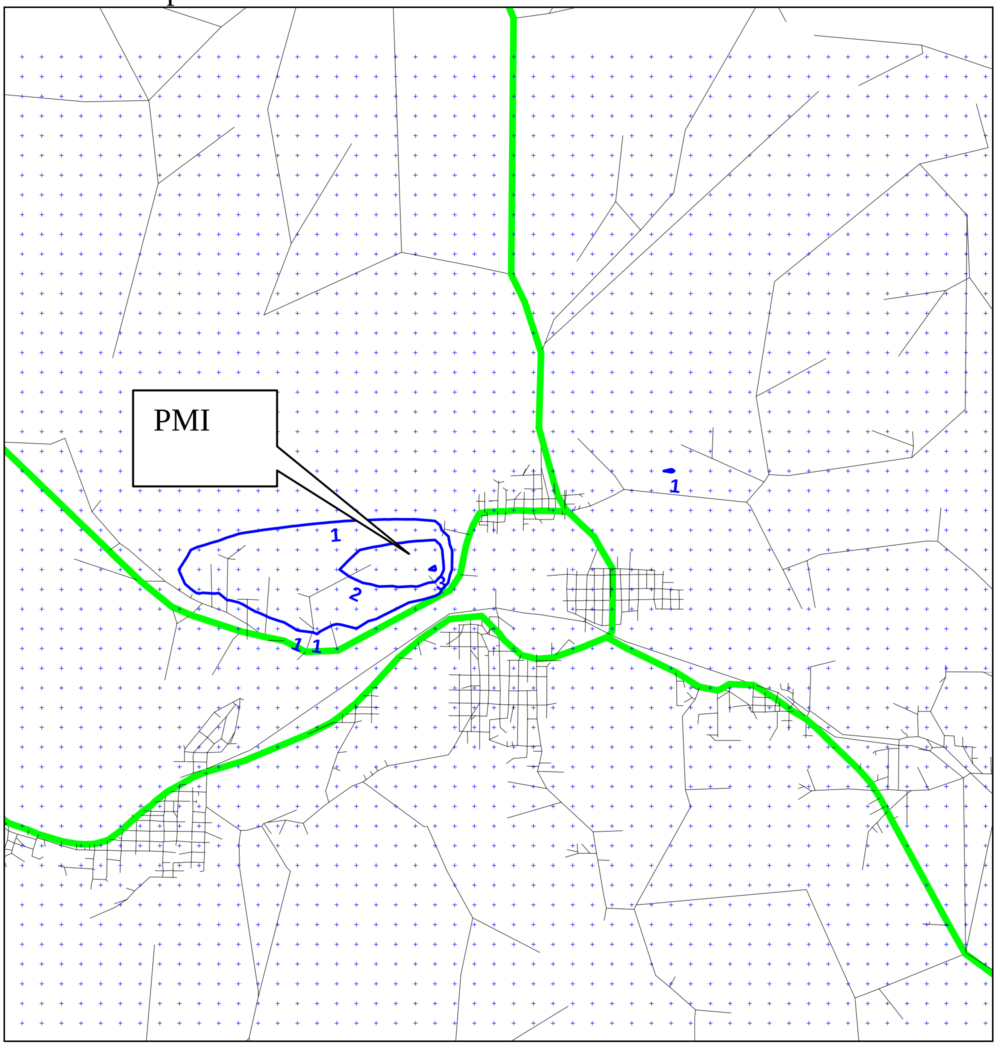
Facility	Annual EMS (lbs/yr)
WEYERHAEUSER - RAYMOND	1

Arsenic

Facility	Annual EMS (lbs/yr)
WEYERHAEUSER - RAYMOND	3

Figure 5-61. Raymond, commercial, cancer.

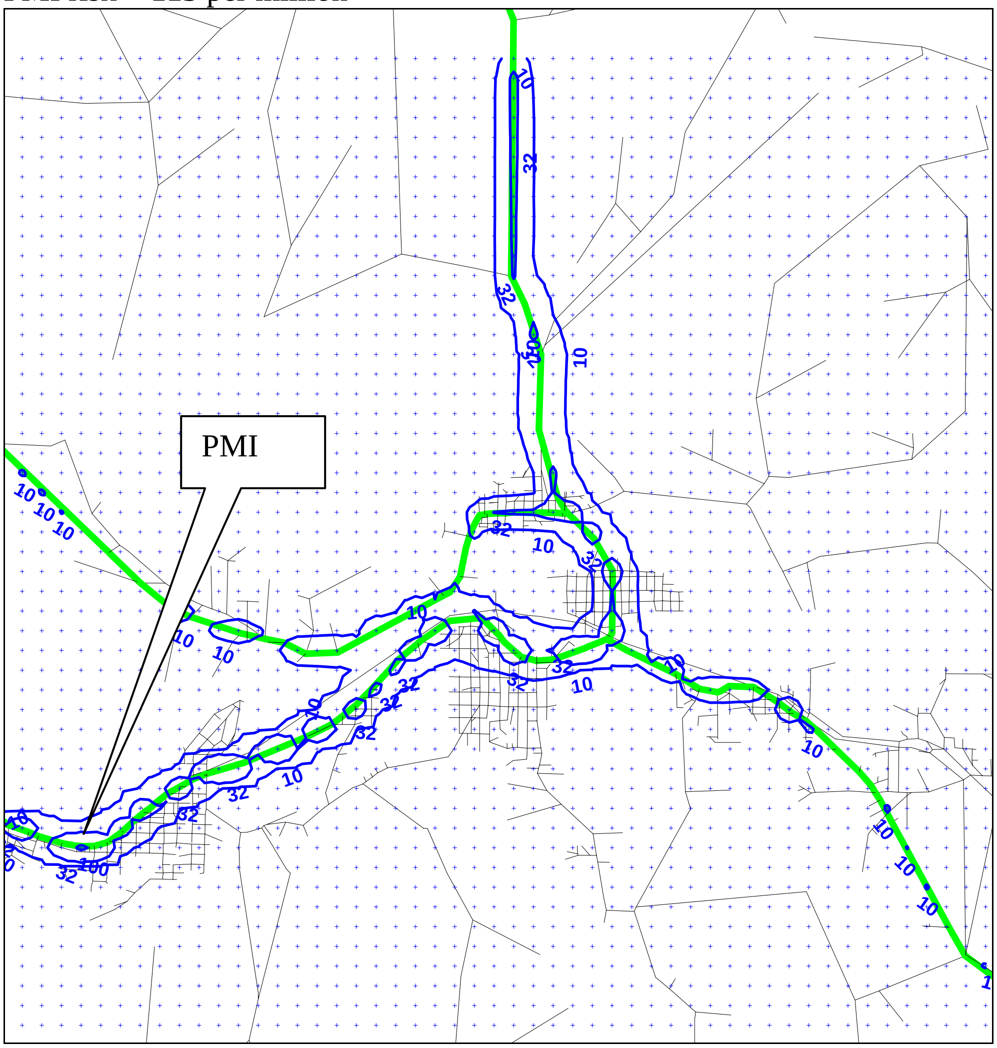
PMI risk =3 per million



5.4.5.2.2 Diesel On-road

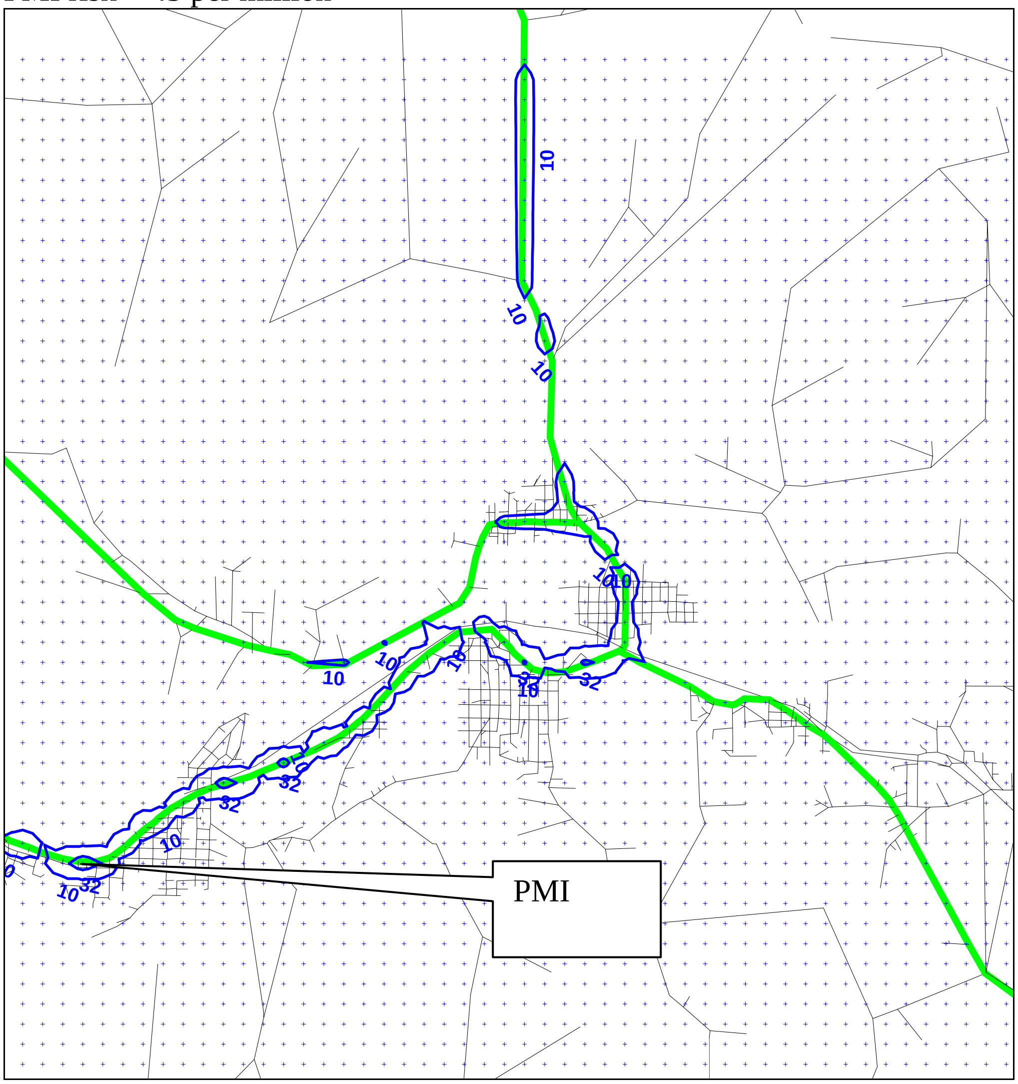
Figure 5-62. Raymond, on-road diesel, cancer.

PMI risk = 113 per million



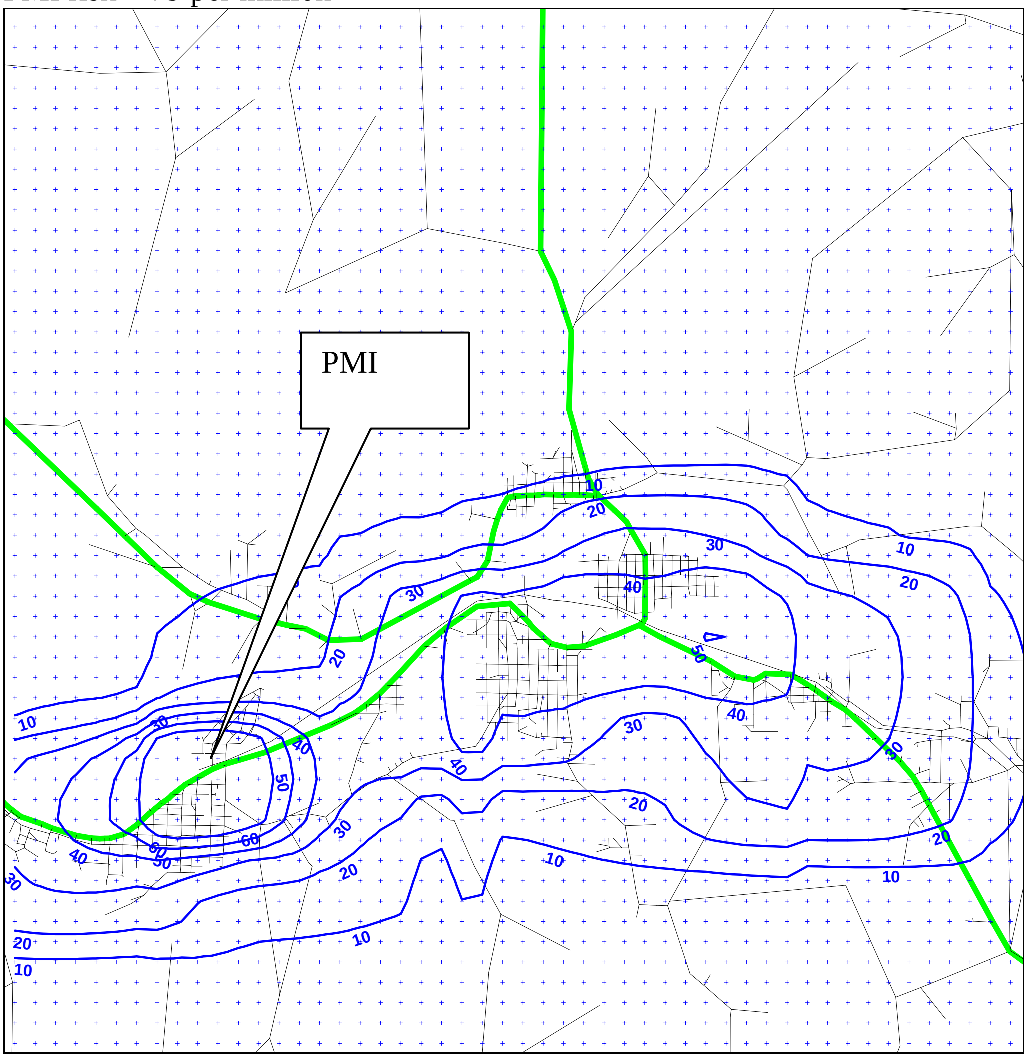
5.4.5.2.3 Gasoline On-road

Figure 5-63. Raymond, on-road gasoline, cancer.
PMI risk = 45 per million



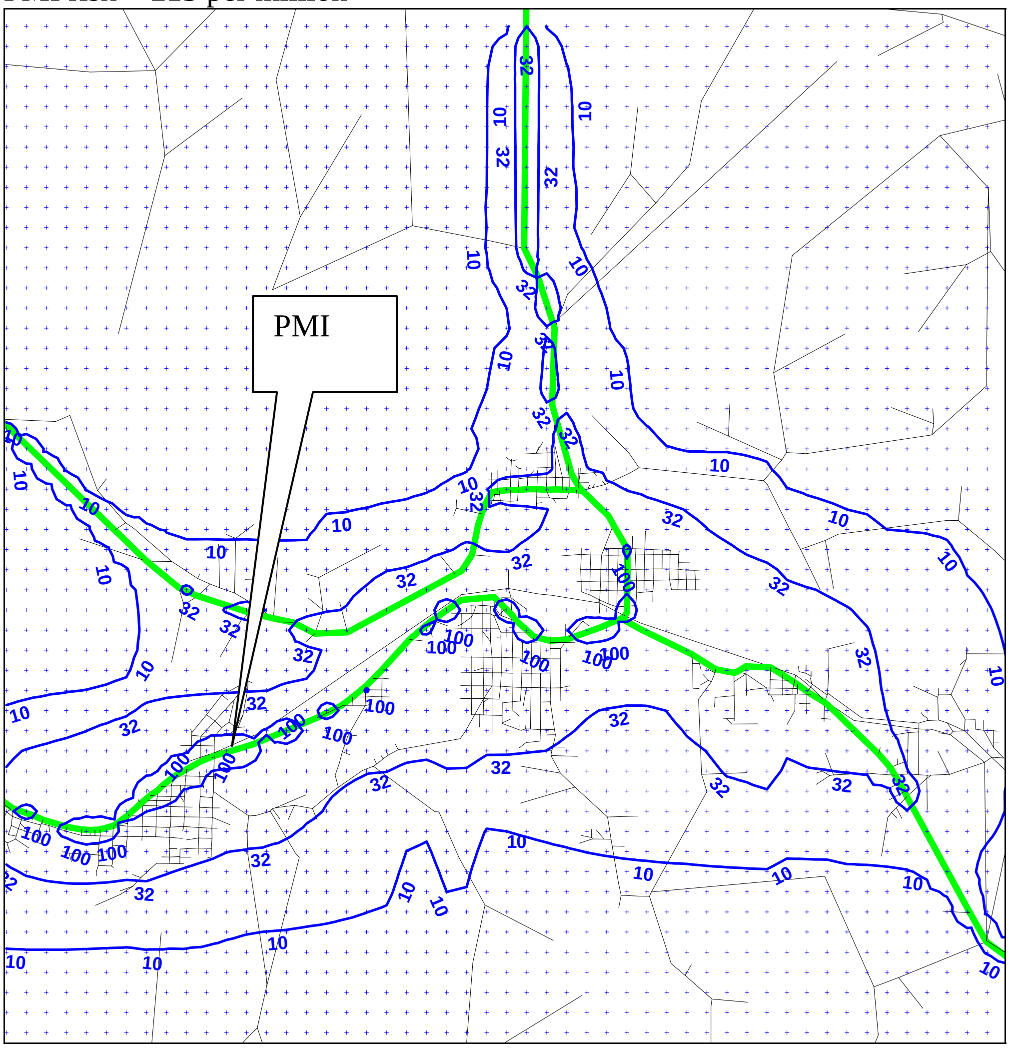
5.4.5.2.4 Wood Stoves and Fireplaces

Figure 5-64. Raymond, wood stoves, cancer.
PMI risk = 79 per million



5.4.5.2.5 Total Cancer Risk

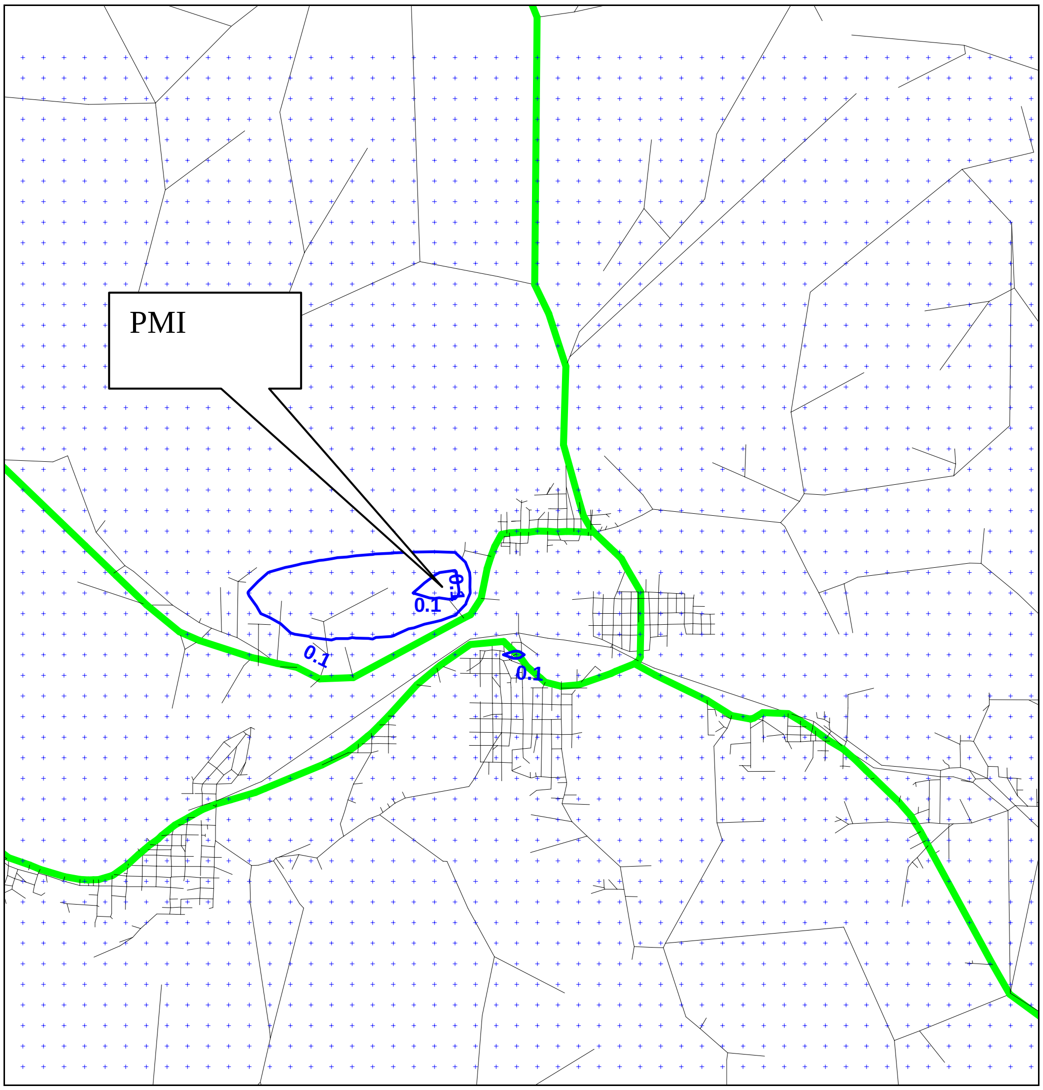
Figure 5-65. Raymond, all sources, cancer.
PMI risk = 213 per million



5.4.5.3 Chronic Non-cancer

5.4.5.3.1 Point Source (Commerical)

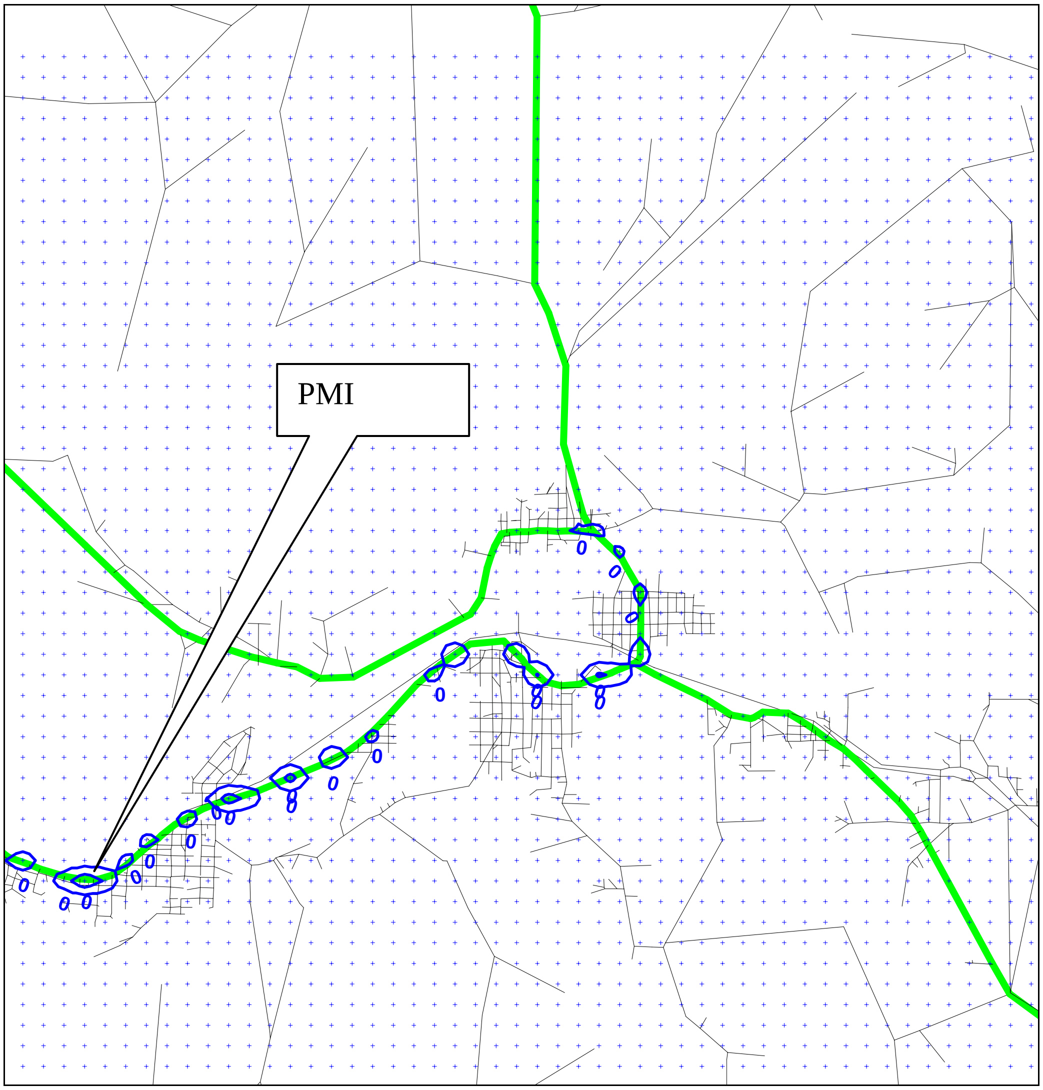
Figure 5-66. Raymond, commercial, chronic non-cancer HHI.
PMI risk = 0.02



5.4.5.3.2 Diesel On-road

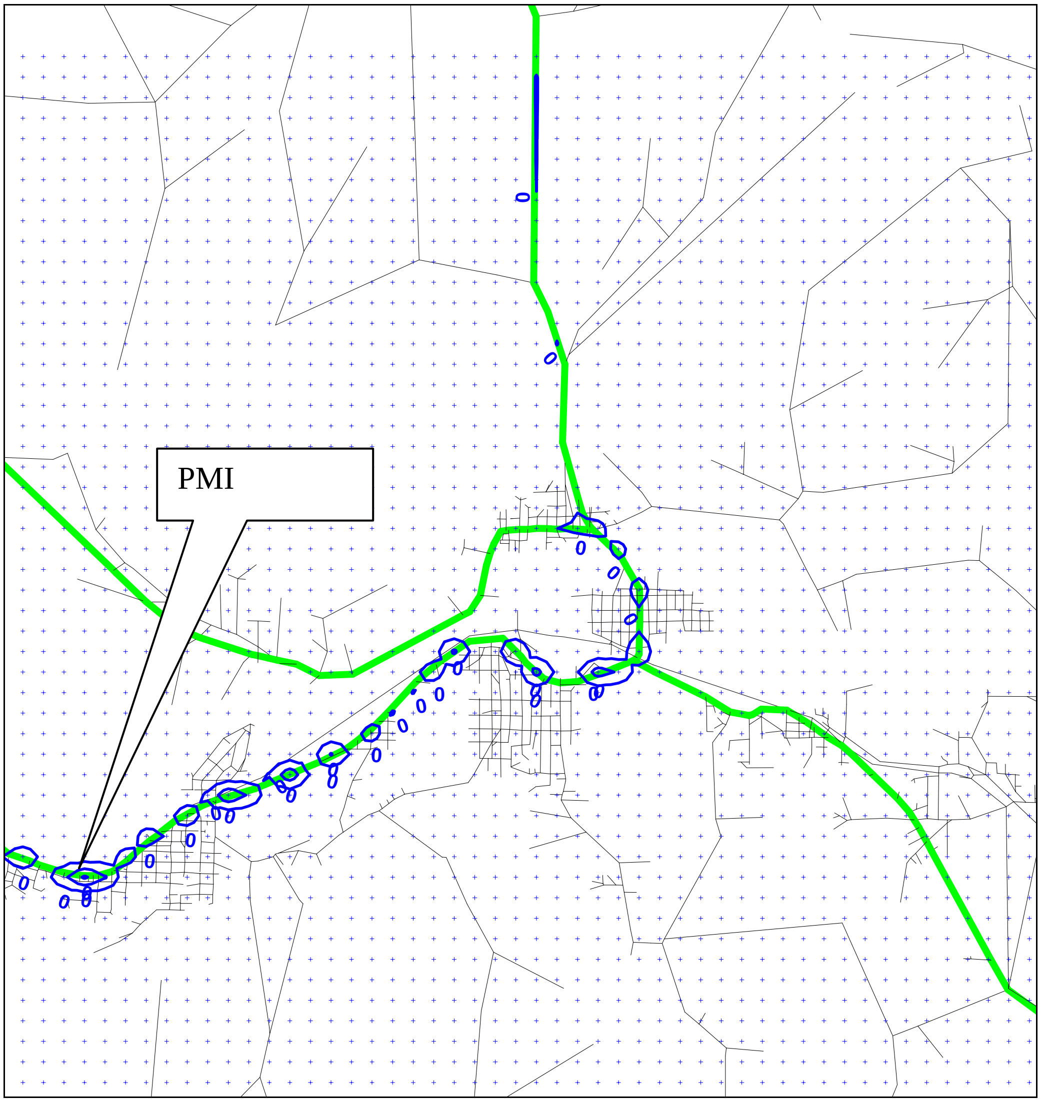
Figure 5-67. Raymond, on-road diesel, chronic non-cancer HHI.

PMI risk = 0.14



5.4.5.3.3 Gasoline On-road

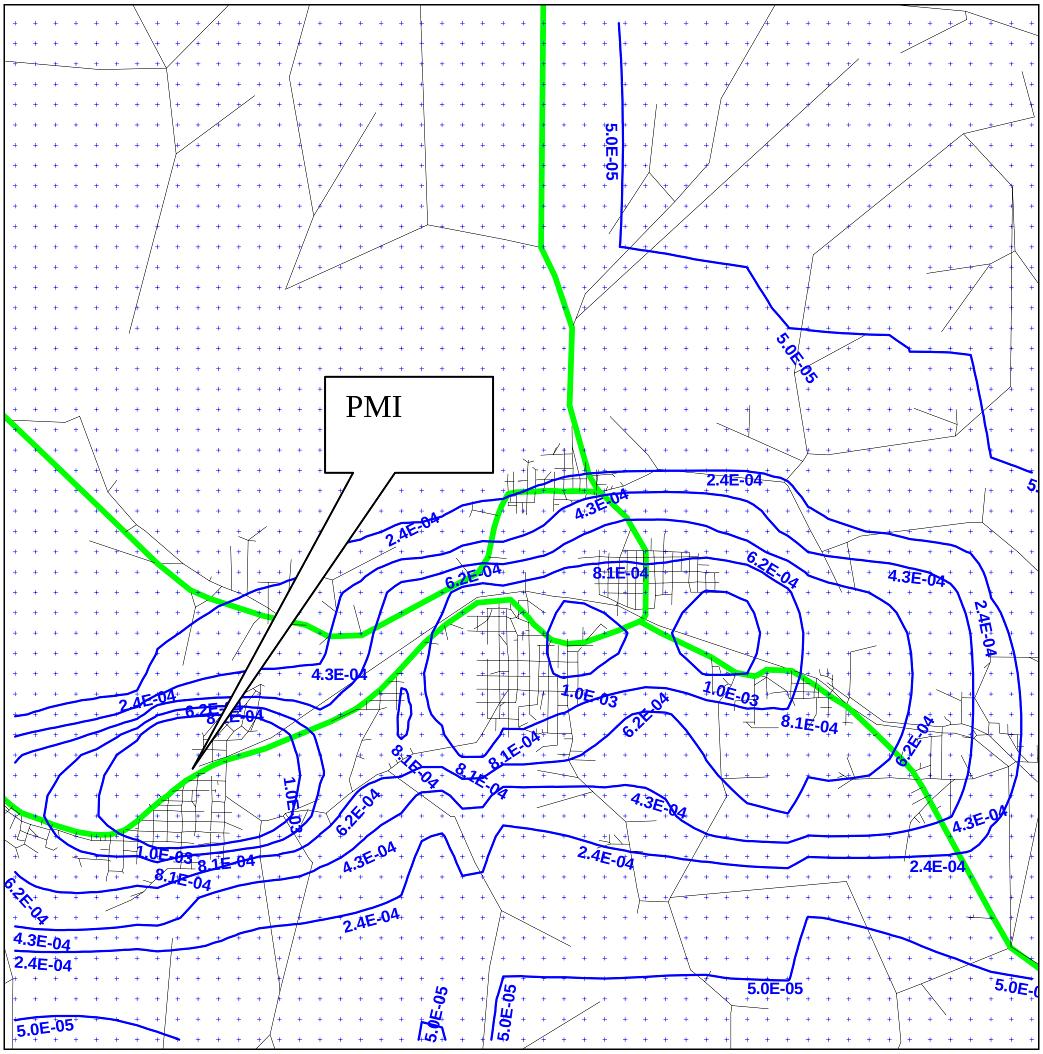
Figure 5-68. Raymond, on-road gasoline, chronic non-cancer HHI.
PMI risk = 0.31



5.4.5.3.4 Wood Stoves and Fireplaces

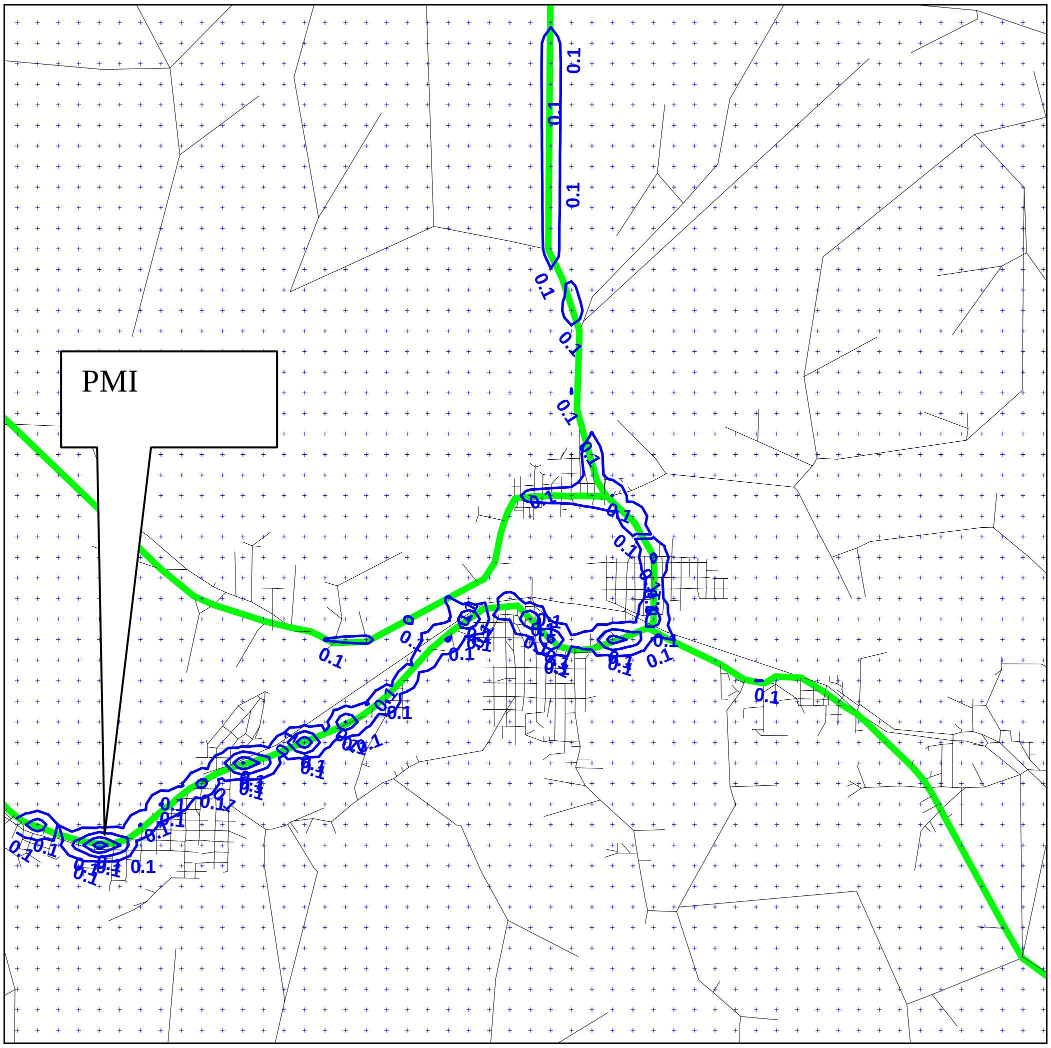
Figure 5-69. Raymond, wood stoves , chronic non-cancer HHI.

PMI risk = 1.7E-3



5.4.5.3.5 Total Chronic Risk

Figure 5-70. Raymond, all sources, chronic non-cancer HHI.
PMI risk = 0.46



5.4.6 Elma

5.4.6.1 Summary

Figure 5-71. Elma study area.

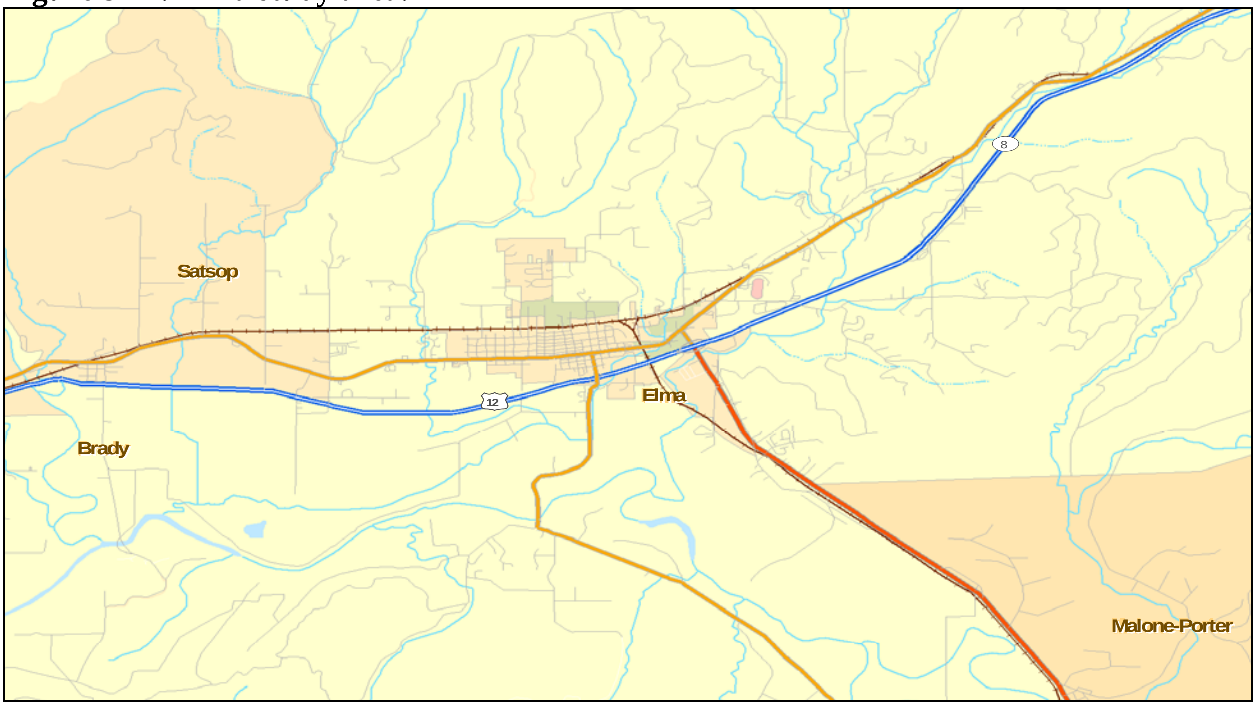


Figure 5-72. Analysis grid and locations of commercial sources. Source locations are indicated by circled X's.

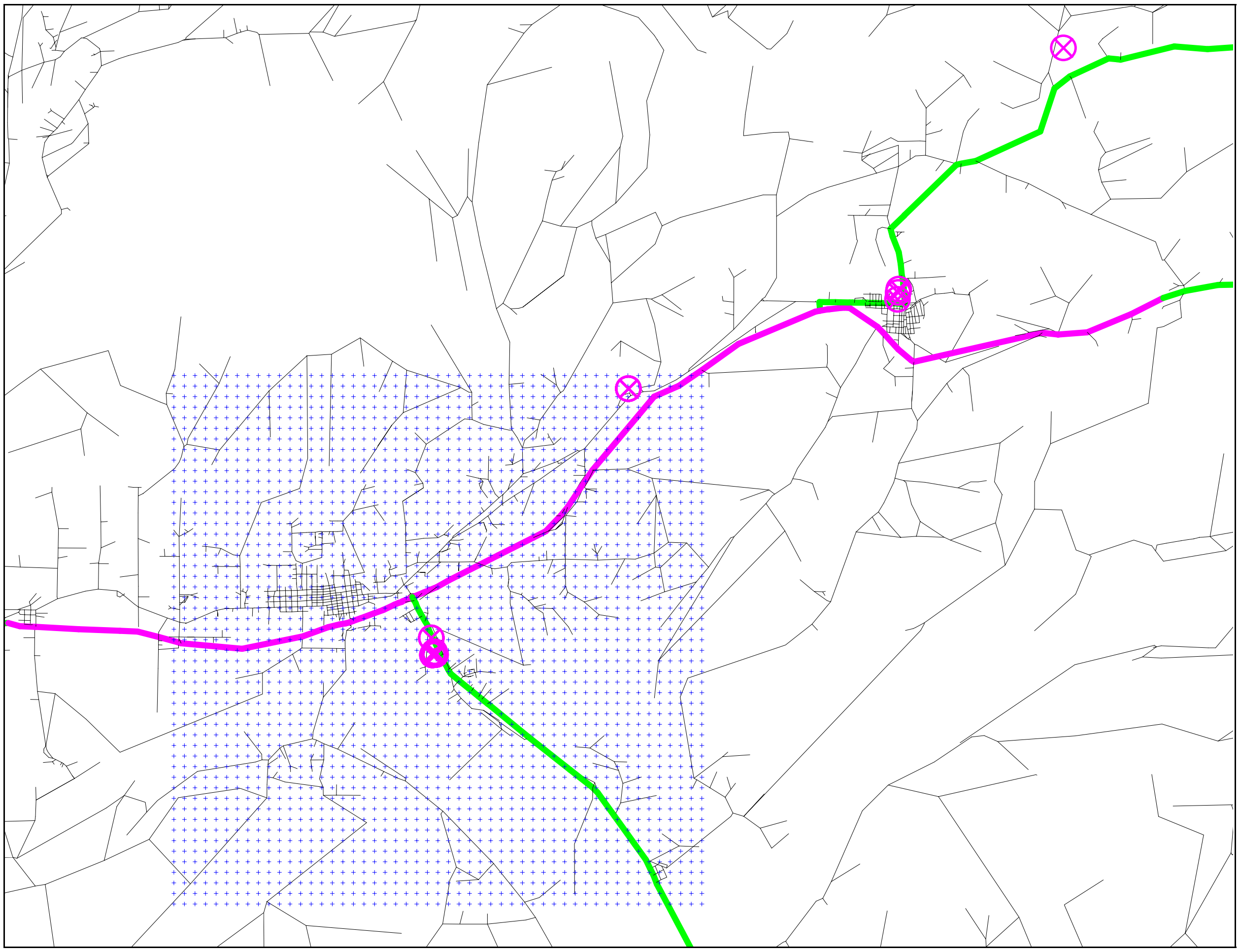


Figure 5-73. Locations of non-commercial sources.
Small magenta squares are locations of on-road freeway, artery, collector and local road sources. Green squares are the boundaries of local road area sources. Blue squares are locations of wood stove sources.

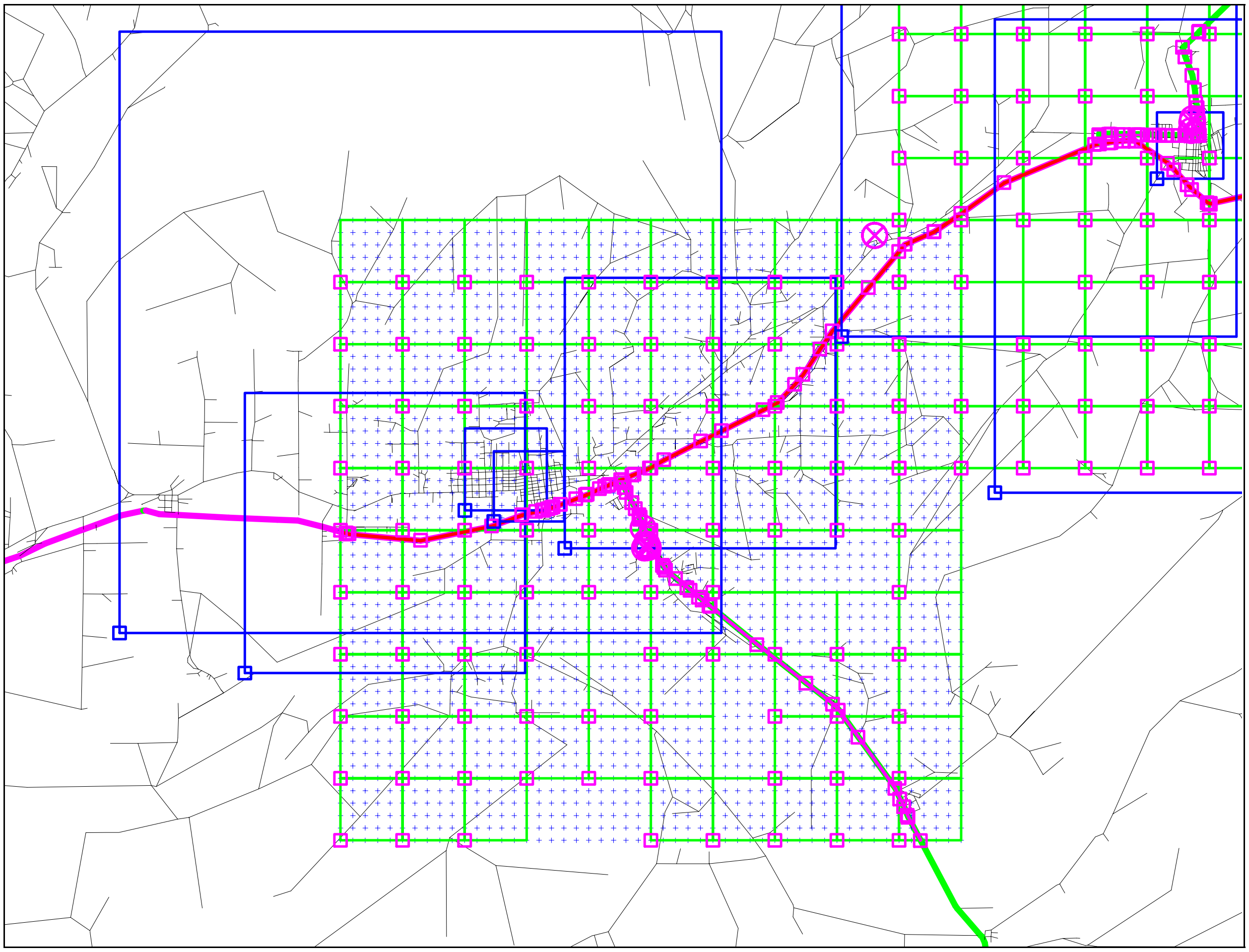
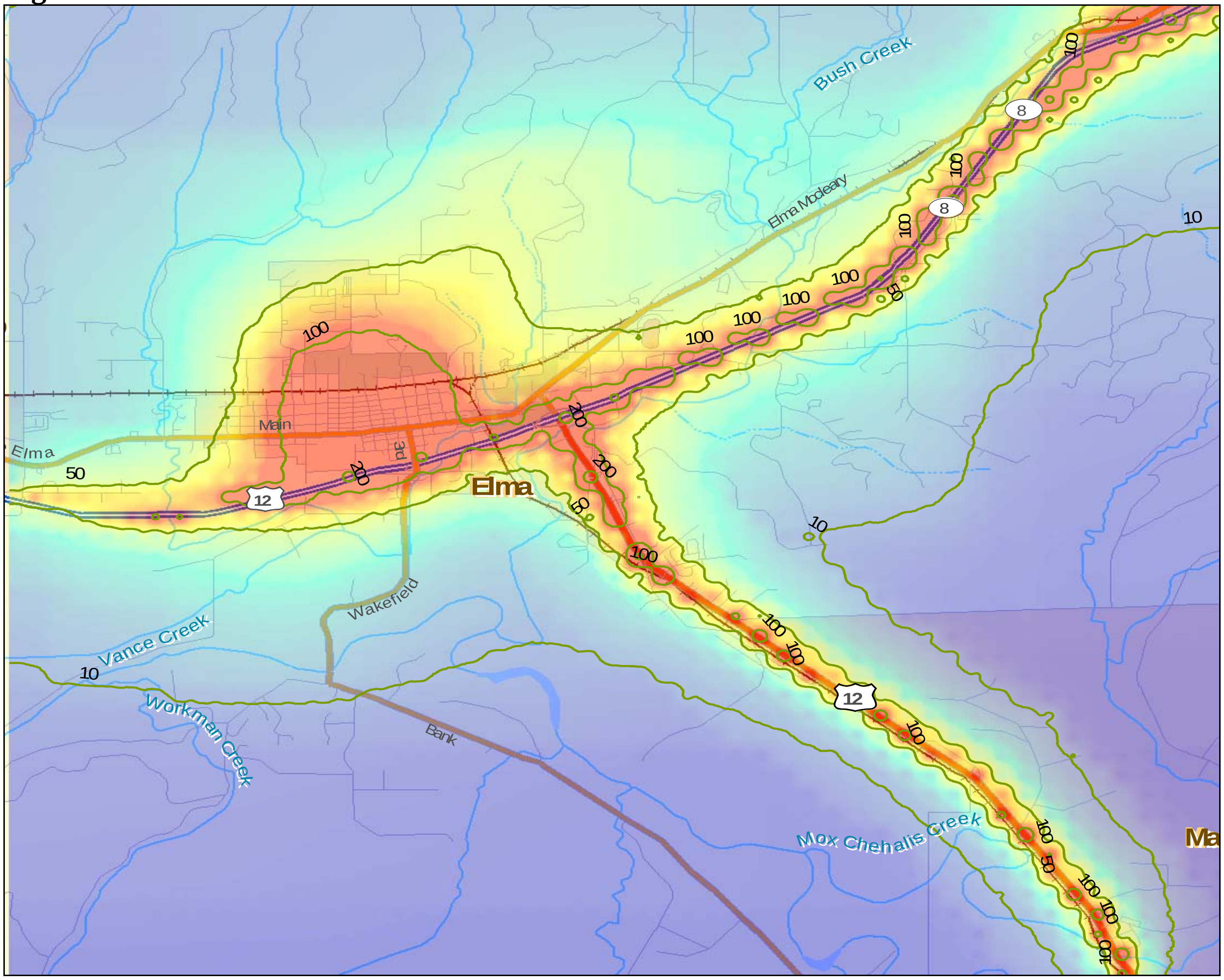


Figure 5-74. Contours of total cancer risk from all sources.



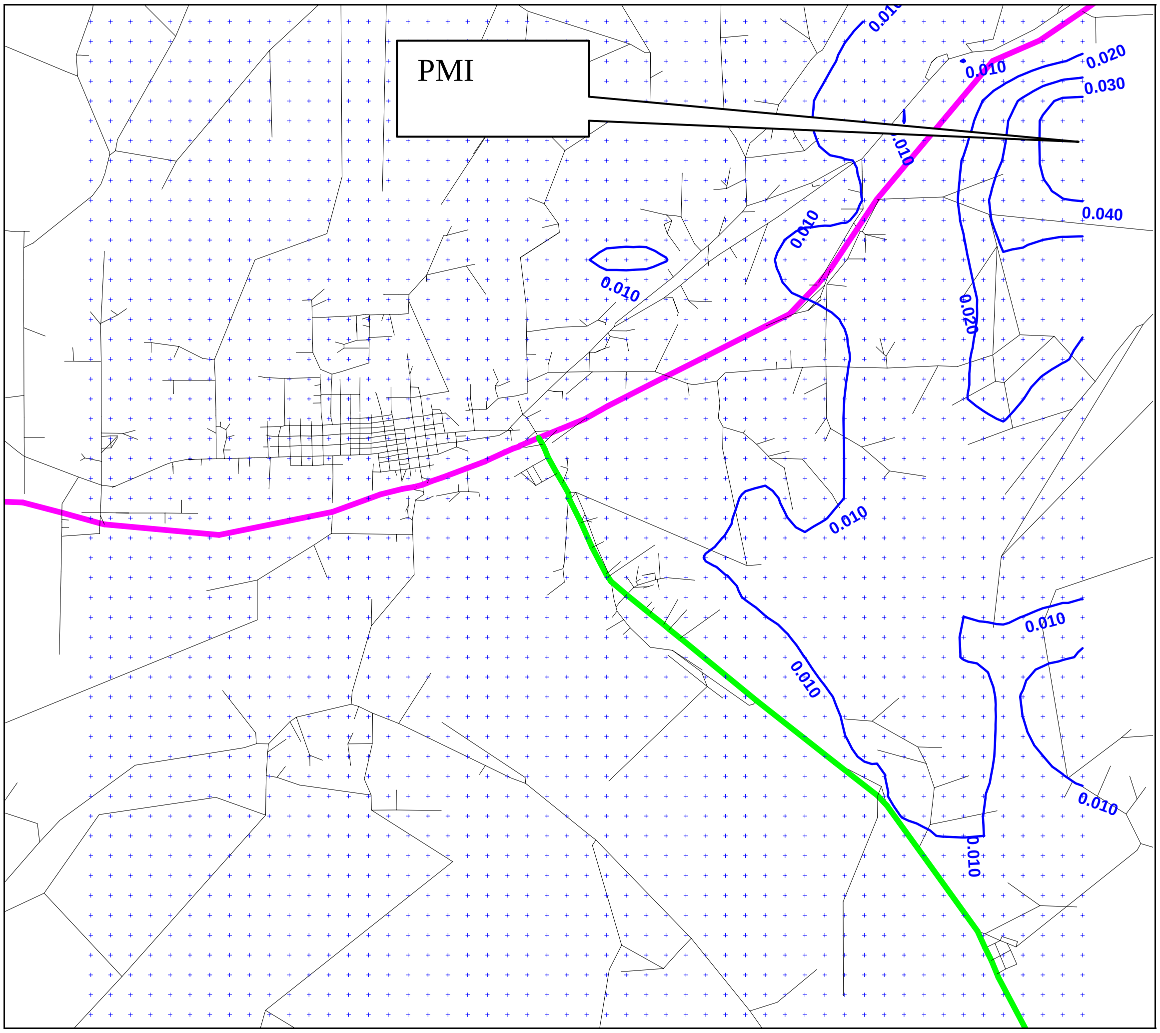
5.4.6.2 Cancer

5.4.6.2.1 Point Source (Commercial)

Table 5-29. Commercial sources included in this study.

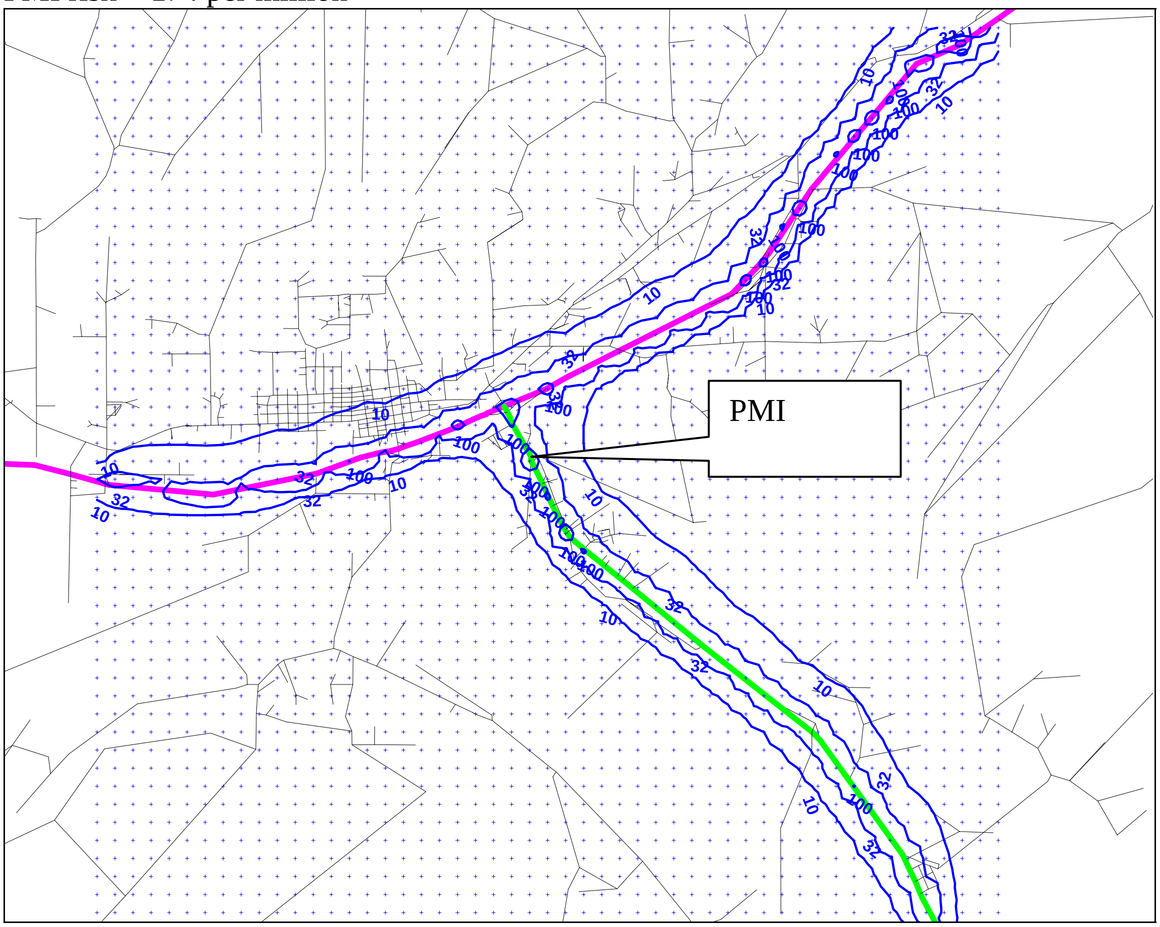
Facility	*Stack*	*UTME meters*	*UTMN meters*
WEYERHAEUSER ELMA VENEER	stack 601	474610	5209751
ROHM HAAS COMPANY	stack 1018	470927	5204762
WELCO-SKOOKUM LUMBER	stack 1041	482849	5216201
WEYERHAEUSER ELMA VENEER	stack 602	474610	5209751
ROHM HAAS COMPANY	stack 1011	470958	5204719
ROHM HAAS COMPANY	stack 1016	470900	5204712
ROHM HAAS COMPANY	stack 1014	470938	5204773
SIMPSON DOOR CO	stack 721	479731	5211635
ROHM HAAS COMPANY	stack 1013	470935	5204769
SIMPSON DOOR CO	stack 723	479708	5211442
ROHM HAAS COMPANY	stack 1012	470931	5204765
SIMPSON DOOR CO	stack 724	479719	5211573
ROHM HAAS COMPANY	stack 1017	470877	5205035

Figure 5-75. Elma, commercial, cancer.
PMI risk = 5E-8



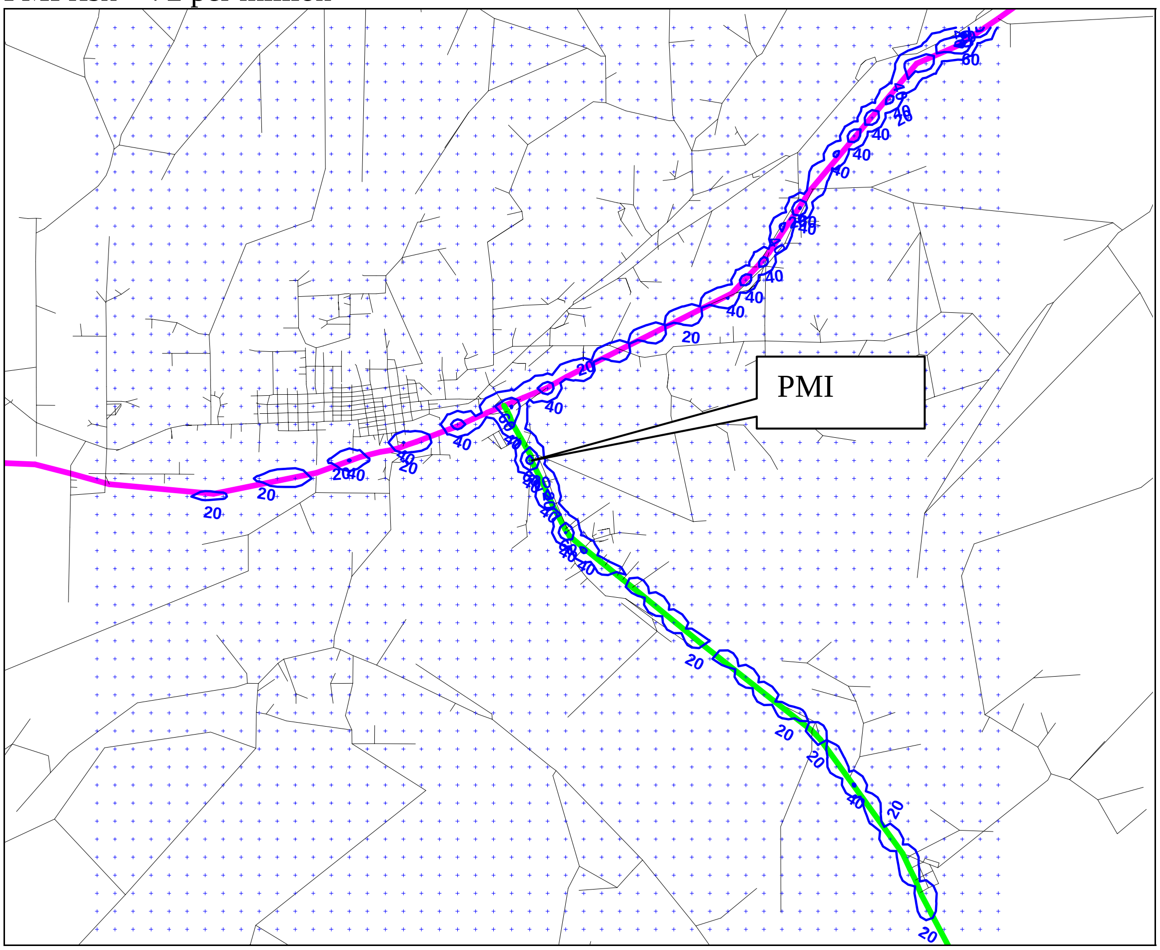
5.4.6.2.2 Diesel On-road

Figure 5-76. Elma, on-road diesel, cancer.
PMI risk = 174 per million



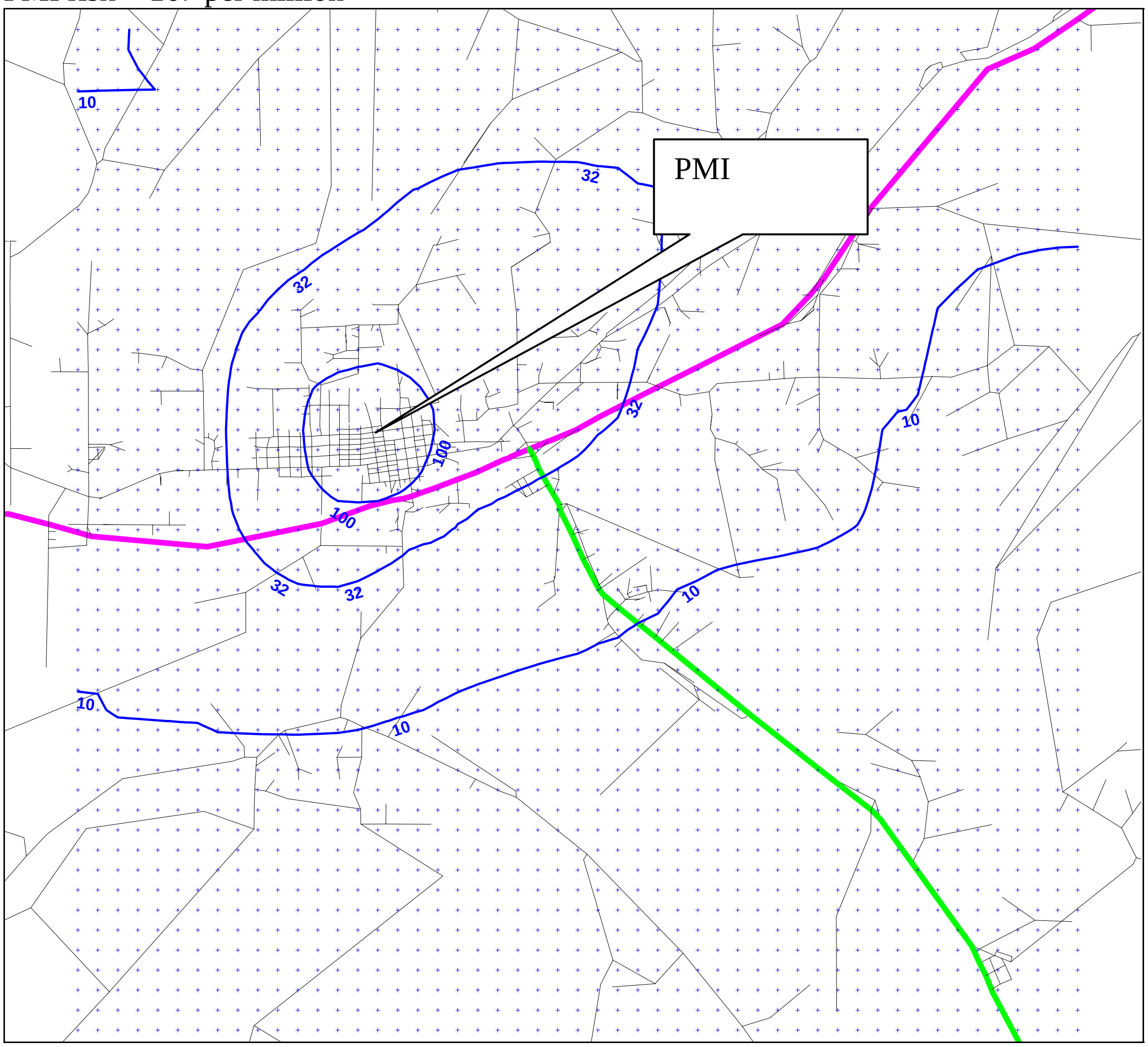
5.4.6.2.3 Gasoline On-road

Figure 5-77. Elma, on-road gasoline, cancer.
PMI risk = 72 per million



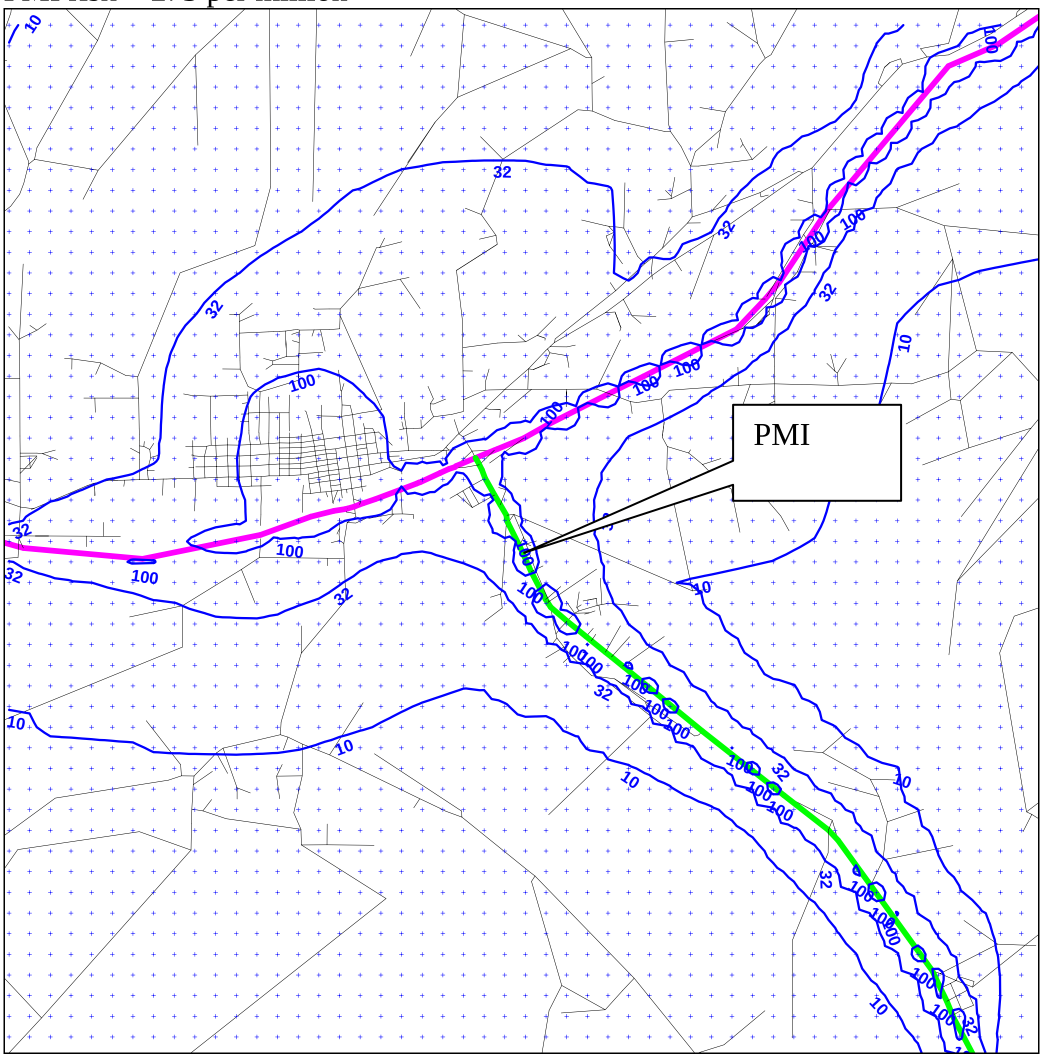
5.4.6.2.4 Wood Stoves and Fireplaces

Figure 5-78. Elma, wood stove, cancer.
PMI risk = 167 per million



5.4.6.2.5 Total Cancer Risk

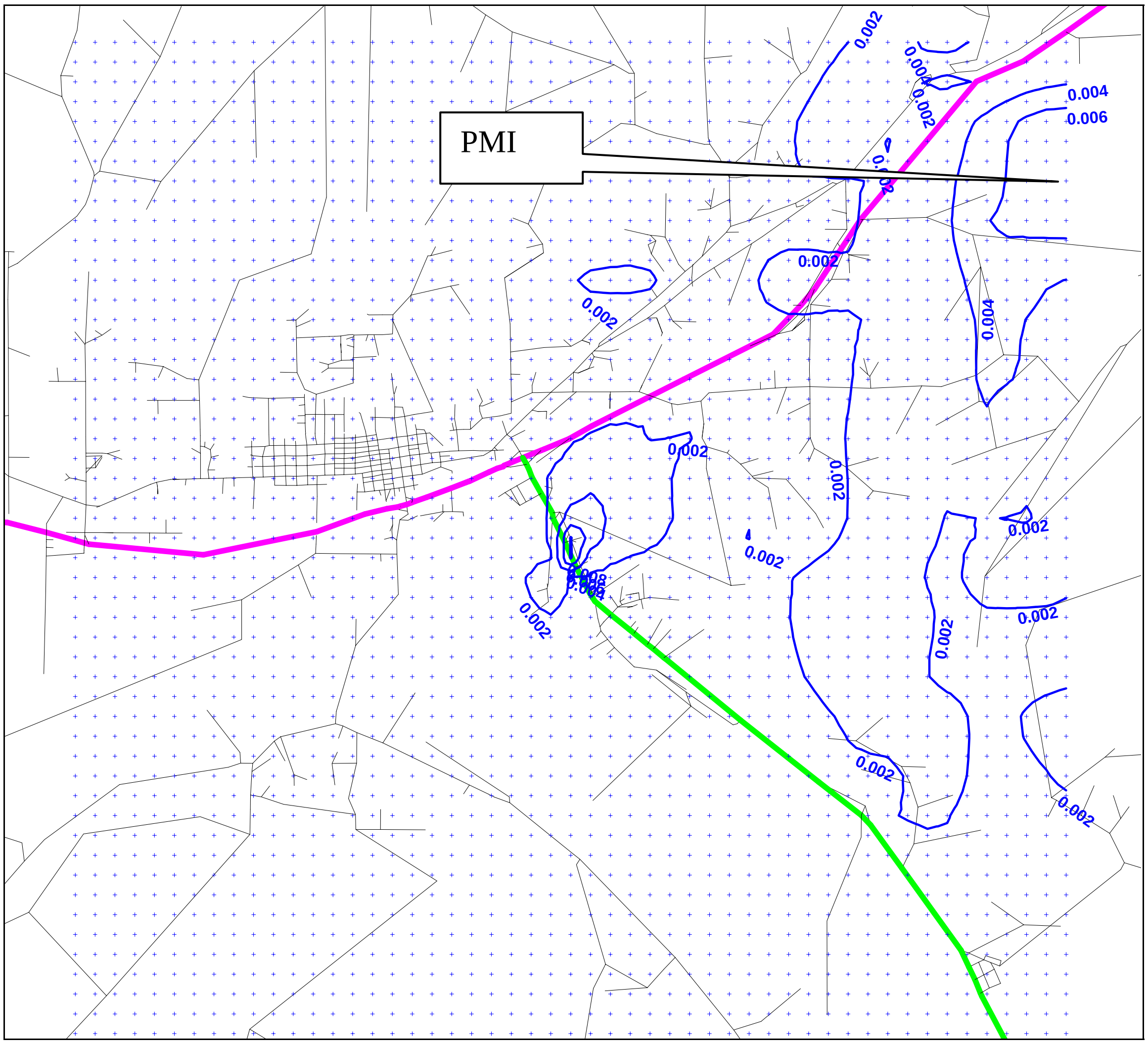
Figure 5-79. Elma, all sources, cancer.
PMI risk = 273 per million



5.4.6.3 Chronic Non-cancer

5.4.6.3.1 Point Source (Commerical)

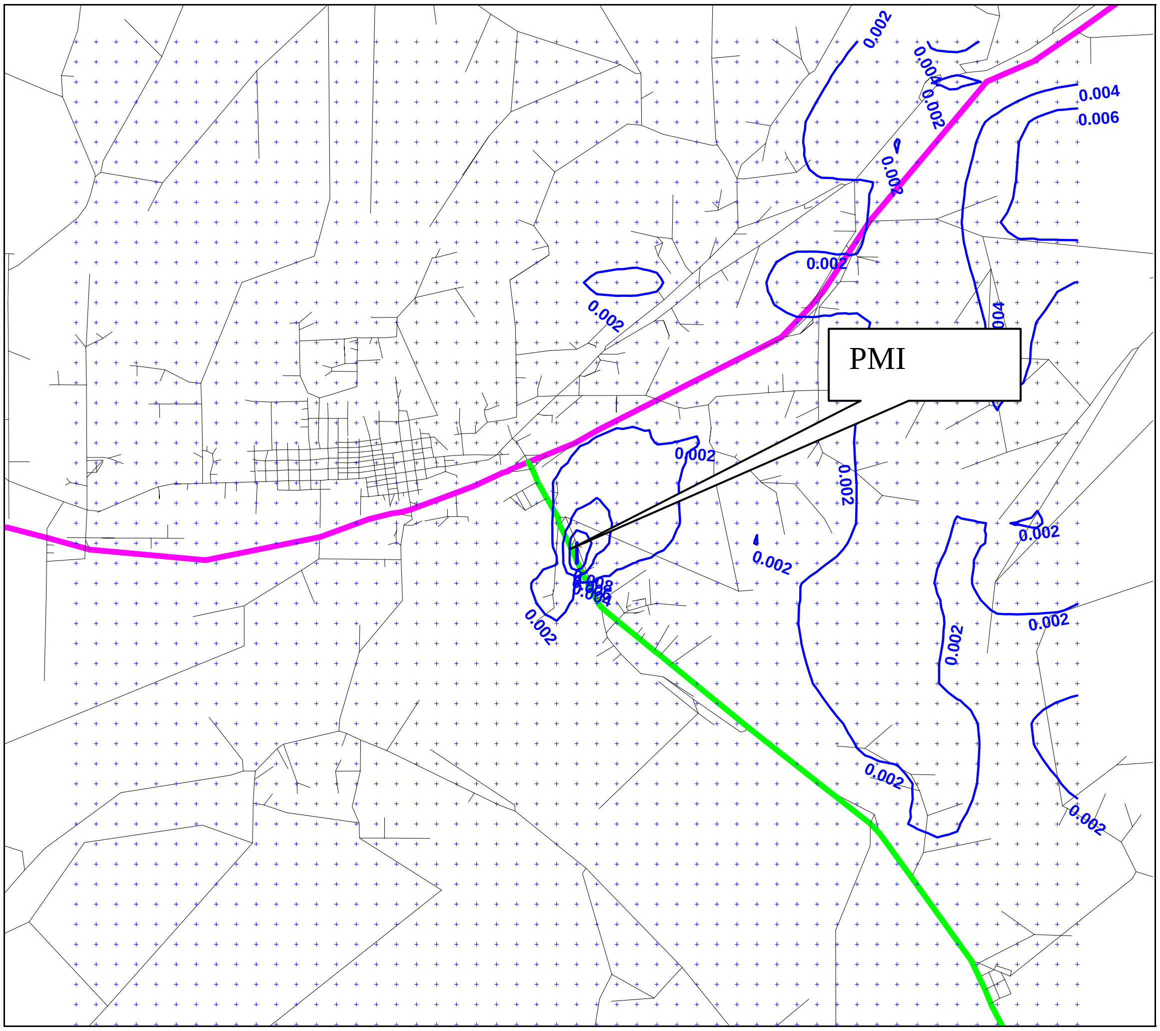
Figure 5-80. Elma, commercial, chronic non-cancer HHI.
PMI risk = 0.0082



5.4.6.3.2 Diesel On-road

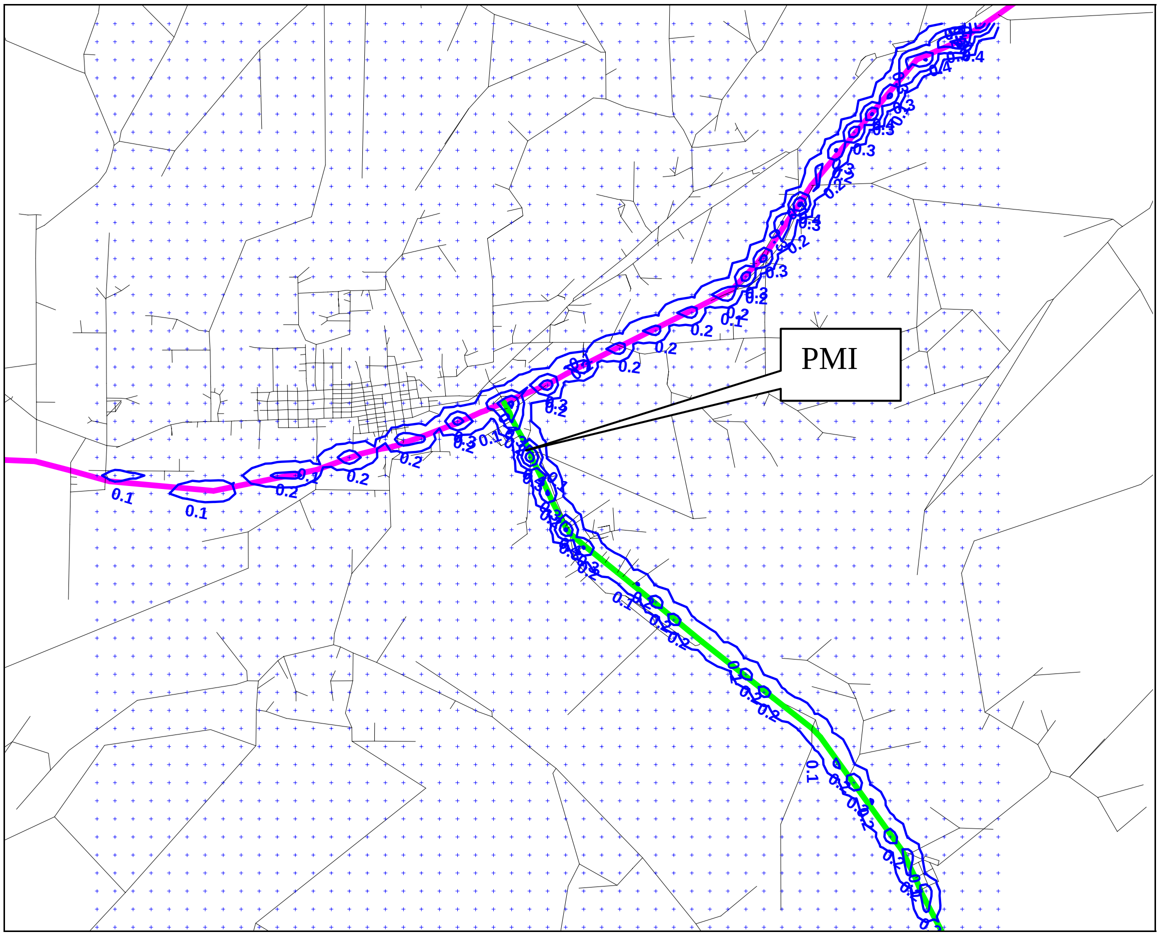
Figure 5-81. Elma, on-road diesel, chronic non-cancer HHI.

PMI risk = 0.20



5.4.6.3.3 Gasoline On-road

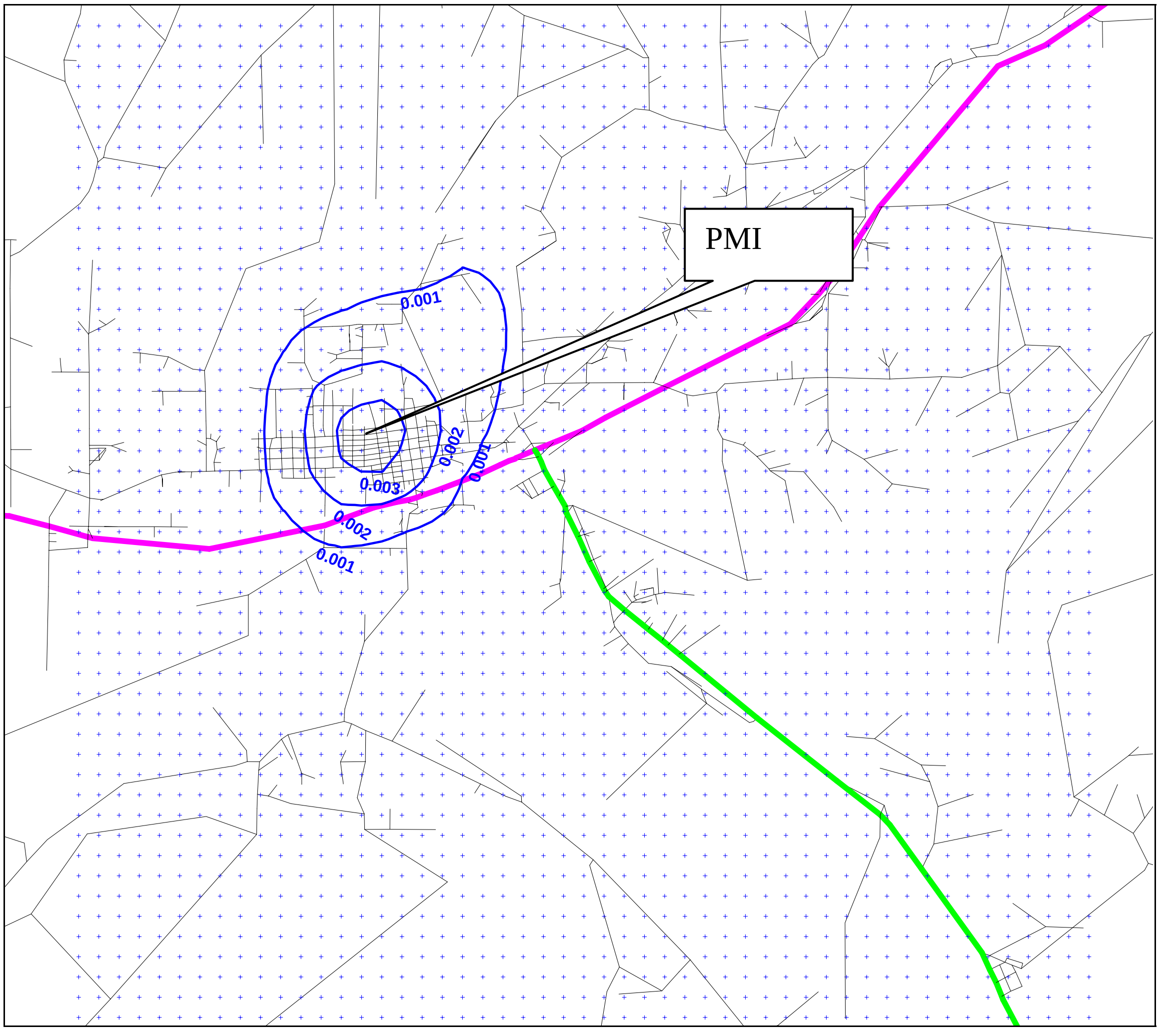
Figure 5-82. Elma, on-road gasoline, chronic non-cancer HHI.
PMI risk = 0.50



5.4.6.3.4 Wood Stoves and Fireplaces

Figure 5-83. Elma, wood stove, chronic non-cancer HHI.

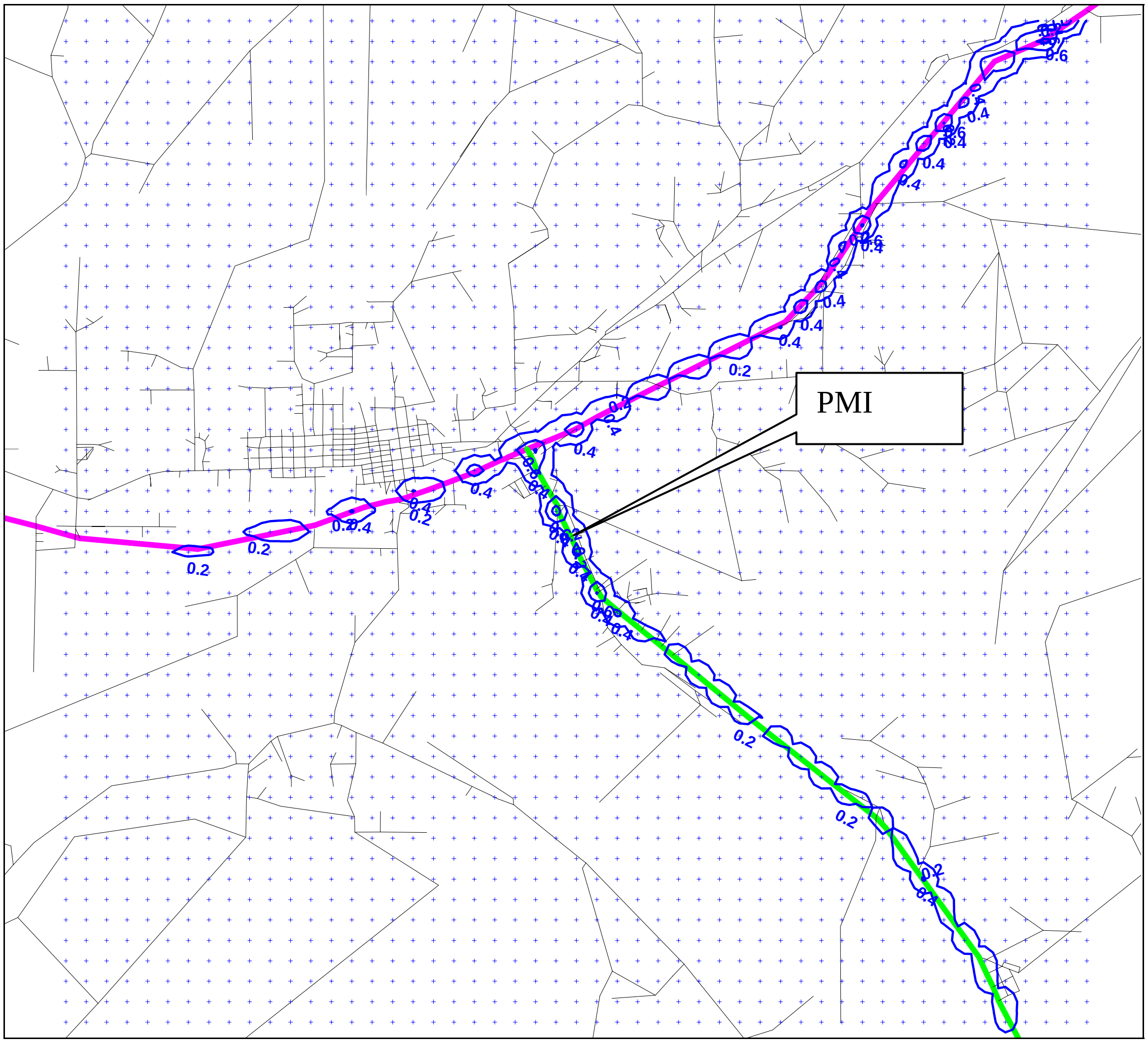
PMI risk = 0.003



5.4.6.3.5 Total Chronic Risk

Figure 5-84. Elma, all sources, chronic non-cancer HHI.

PMI risk = 0.723



5.4.7 McCleary

5.4.7.1 Summary

Figure 5-85. McCleary study area.

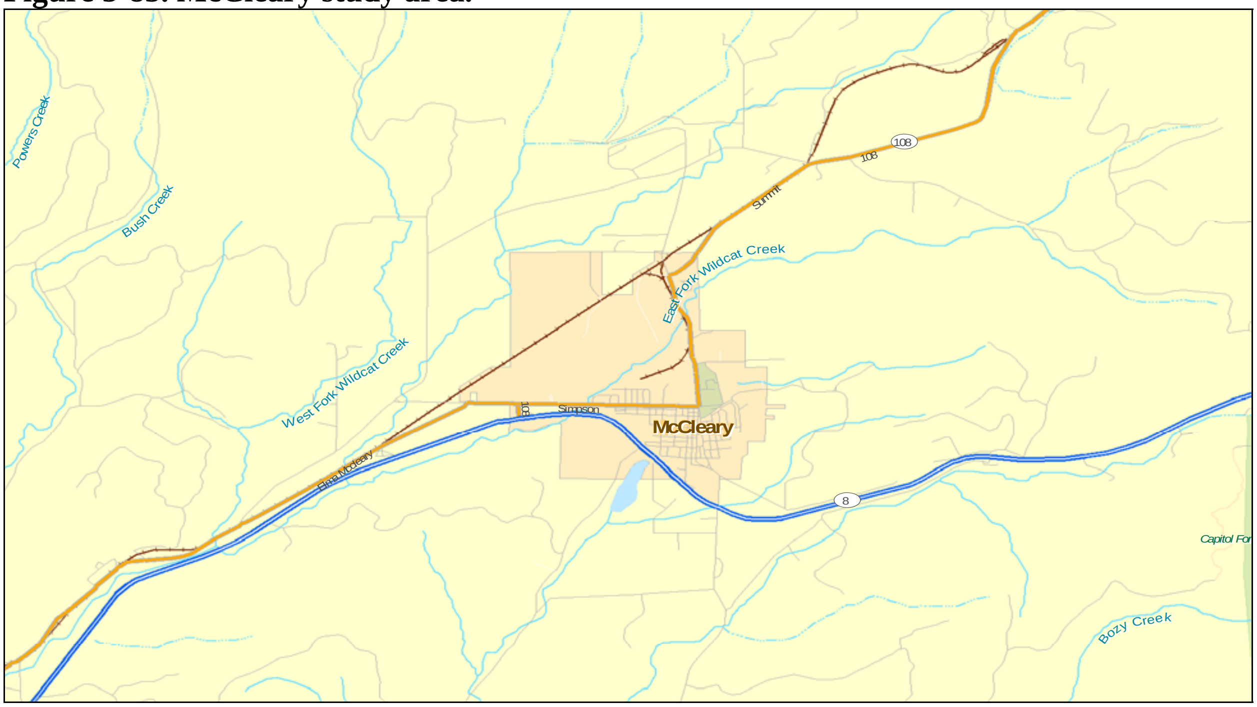


Figure 5-86. Analysis grid and locations of commercial sources. Source locations are indicated by circled X's..

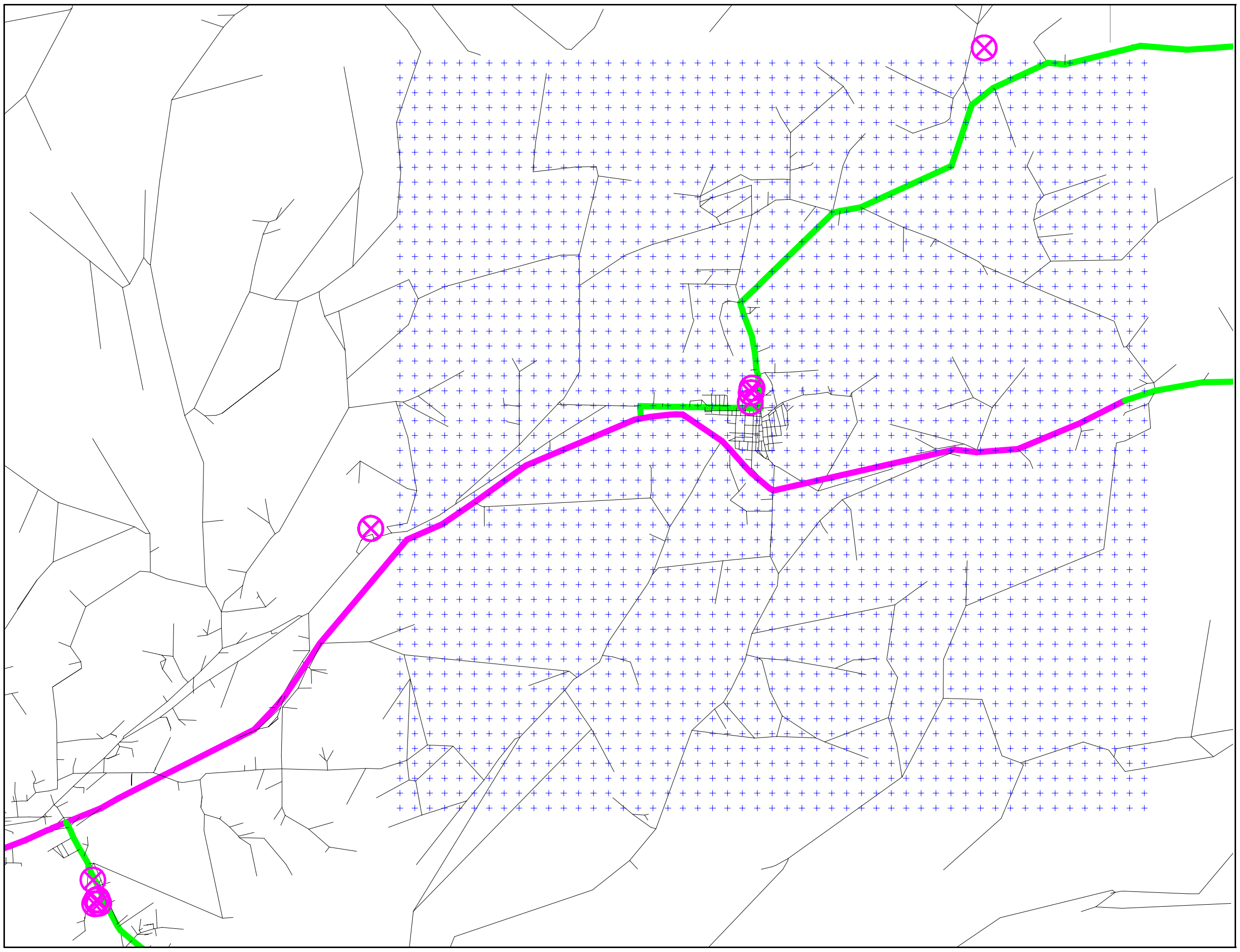


Figure 5-87. Locations of non-commercial sources.
Small magenta squares are locations of on-road freeway, artery, collector and local road sources. Green squares are the boundaries of local road area sources. Blue squares are locations of wood stove sources.

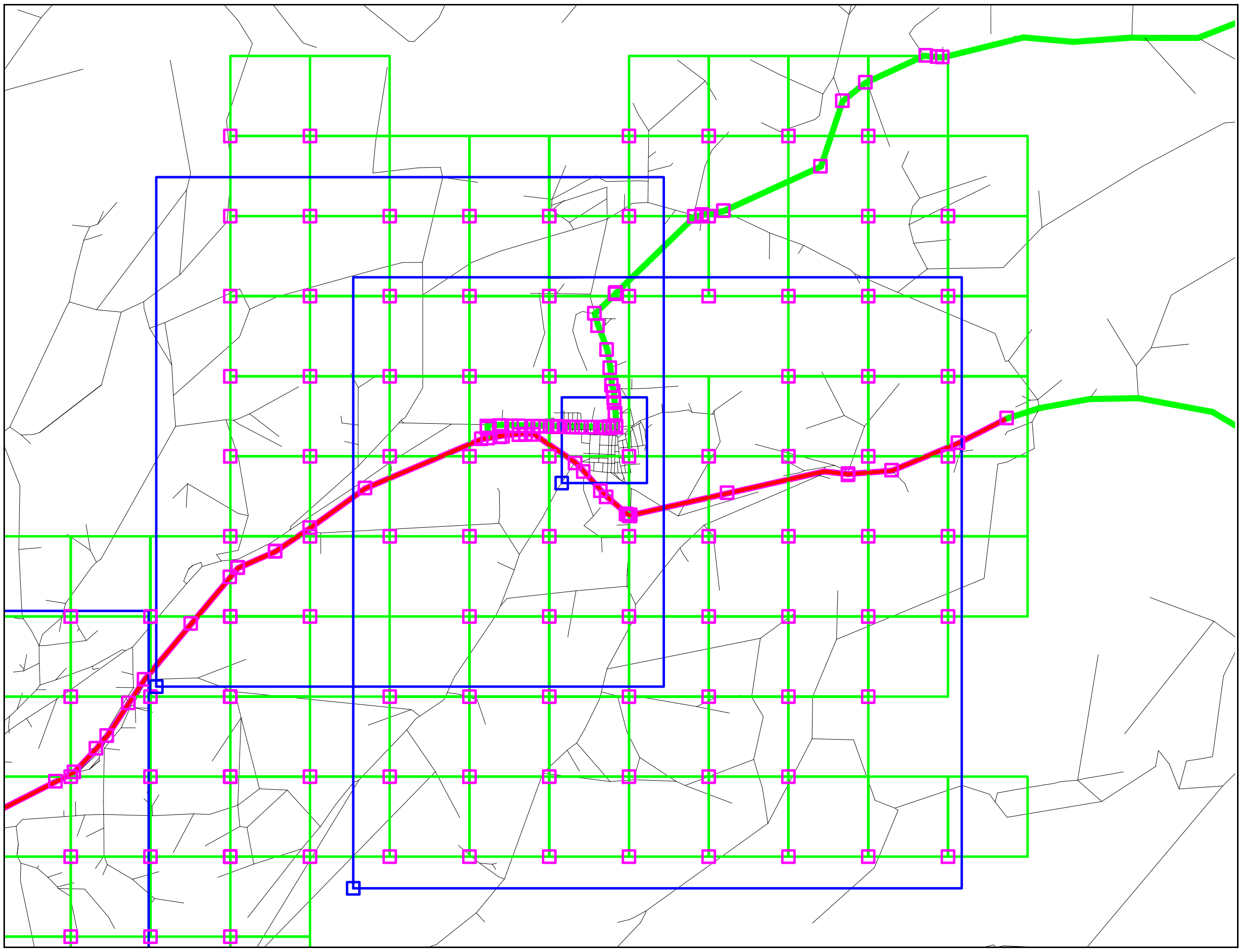
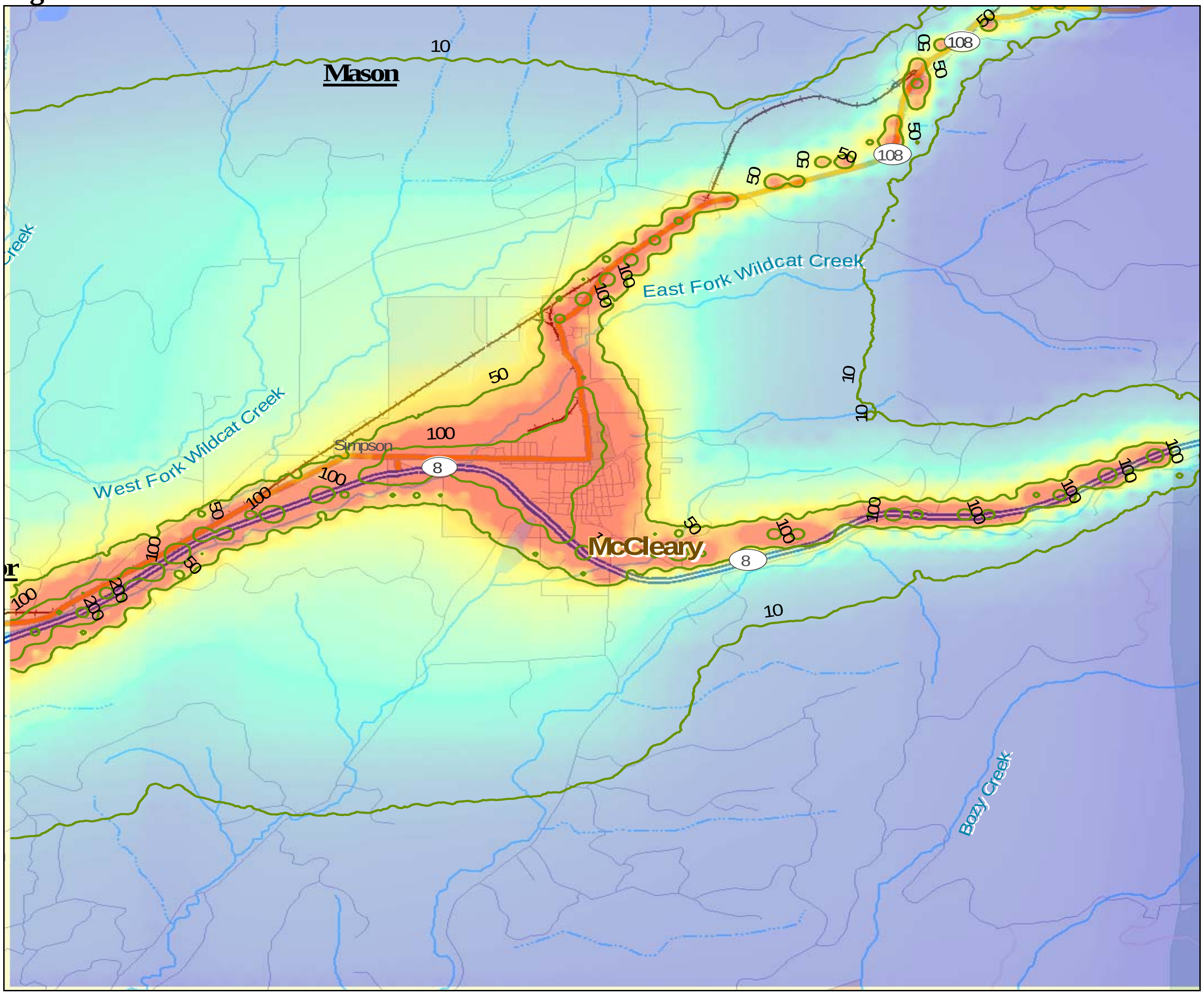


Figure 5-88. Contours of total cancer risk from all sources.



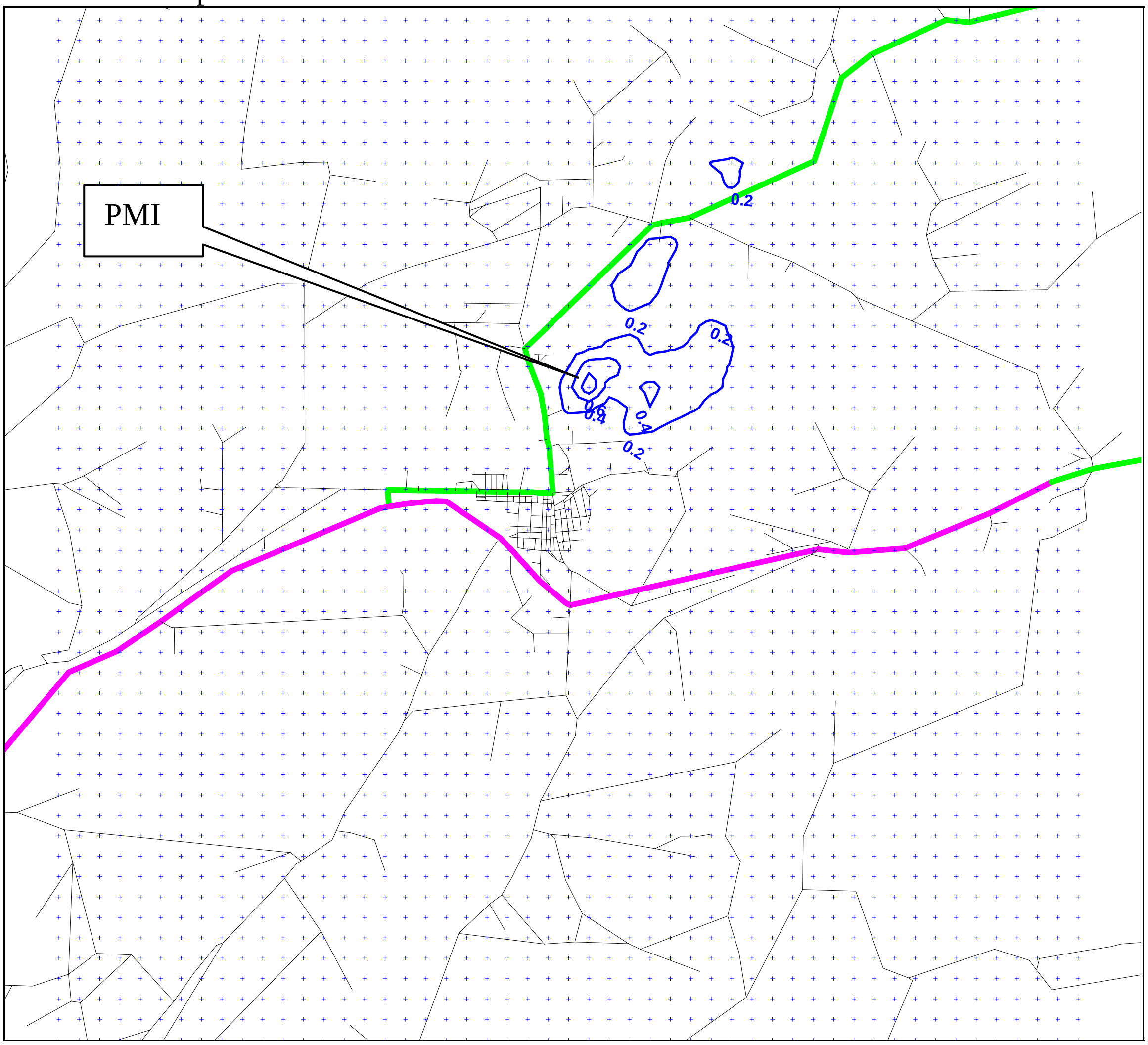
5.4.7.2 Cancer

5.4.7.2.1 Point Source (Commerical)

Figure 5-89. Commercial sources included in this study.

Facility	*Stack*	*UTME*	*UTMN*
		meters	*meters*
WEYERHAEUSER ELMA VENEER	stack 601	474610	5209751
ROHM HAAS COMPANY	stack 1018	470927	5204762
WELCO-SKOOKUM LUMBER	stack 1041	482849	5216201
WEYERHAEUSER ELMA VENEER	stack 602	474610	5209751
ROHM HAAS COMPANY	stack 1011	470958	5204719
ROHM HAAS COMPANY	stack 1016	470900	5204712
ROHM HAAS COMPANY	stack 1014	470938	5204773
SIMPSON DOOR CO	stack 721	479731	5211635
ROHM HAAS COMPANY	stack 1013	470935	5204769
SIMPSON DOOR CO	stack 723	479708	5211442
ROHM HAAS COMPANY	stack 1012	470931	5204765
SIMPSON DOOR CO	stack 724	479719	5211573
ROHM HAAS COMPANY	stack 1017	470877	5205035

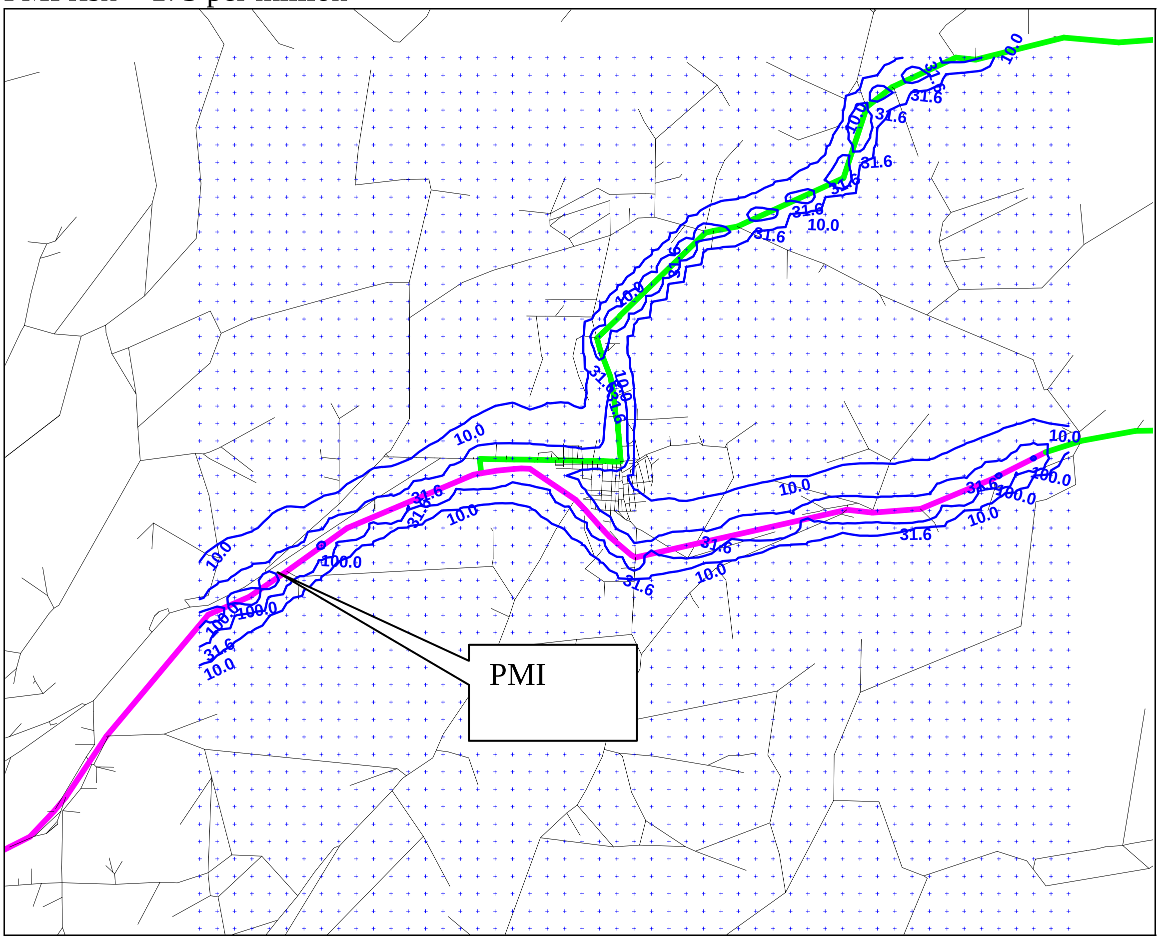
Figure 5-90. McCleary, commercial, cancer.
PMI risk = 0.7 per million



5.4.7.2.2 Diesel On-road

Figure 5-91. McCleary, on-road diesel, cancer.

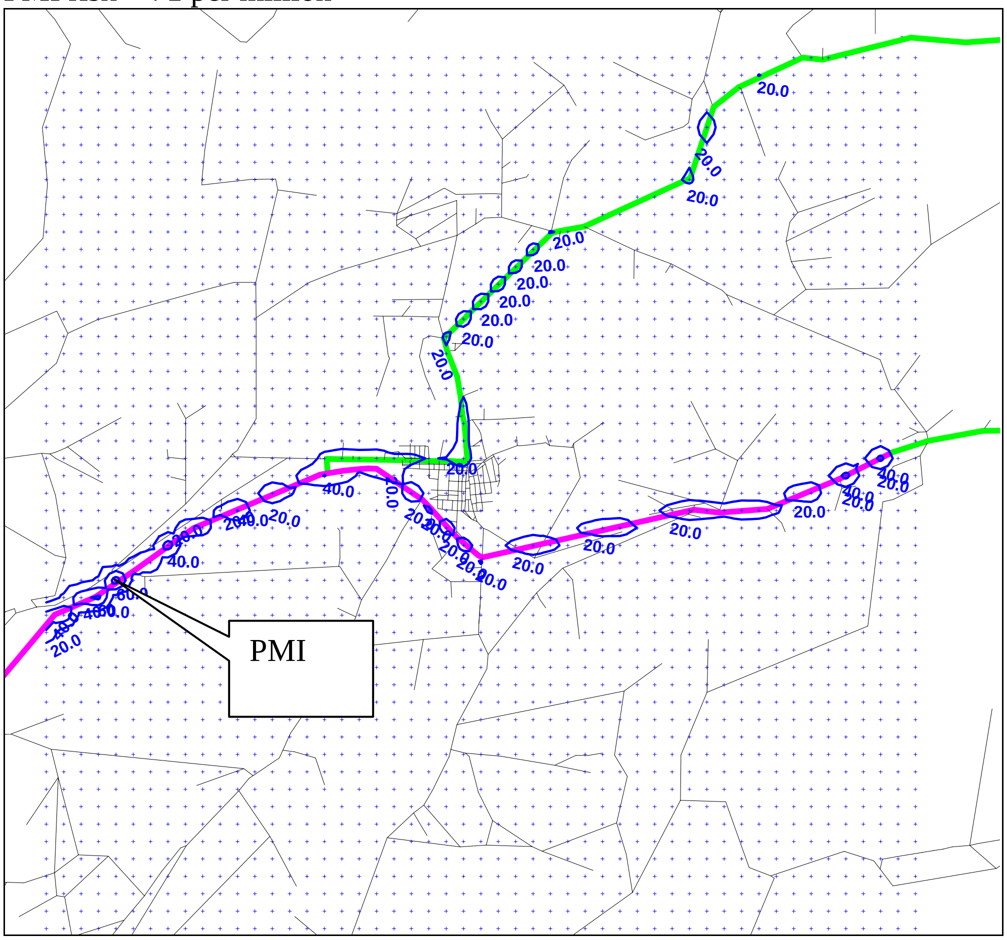
PMI risk = 173 per million



5.4.7.2.3 Gasoline On-road

Figure 5-92. McCleary, on-road gasoline, cancer.

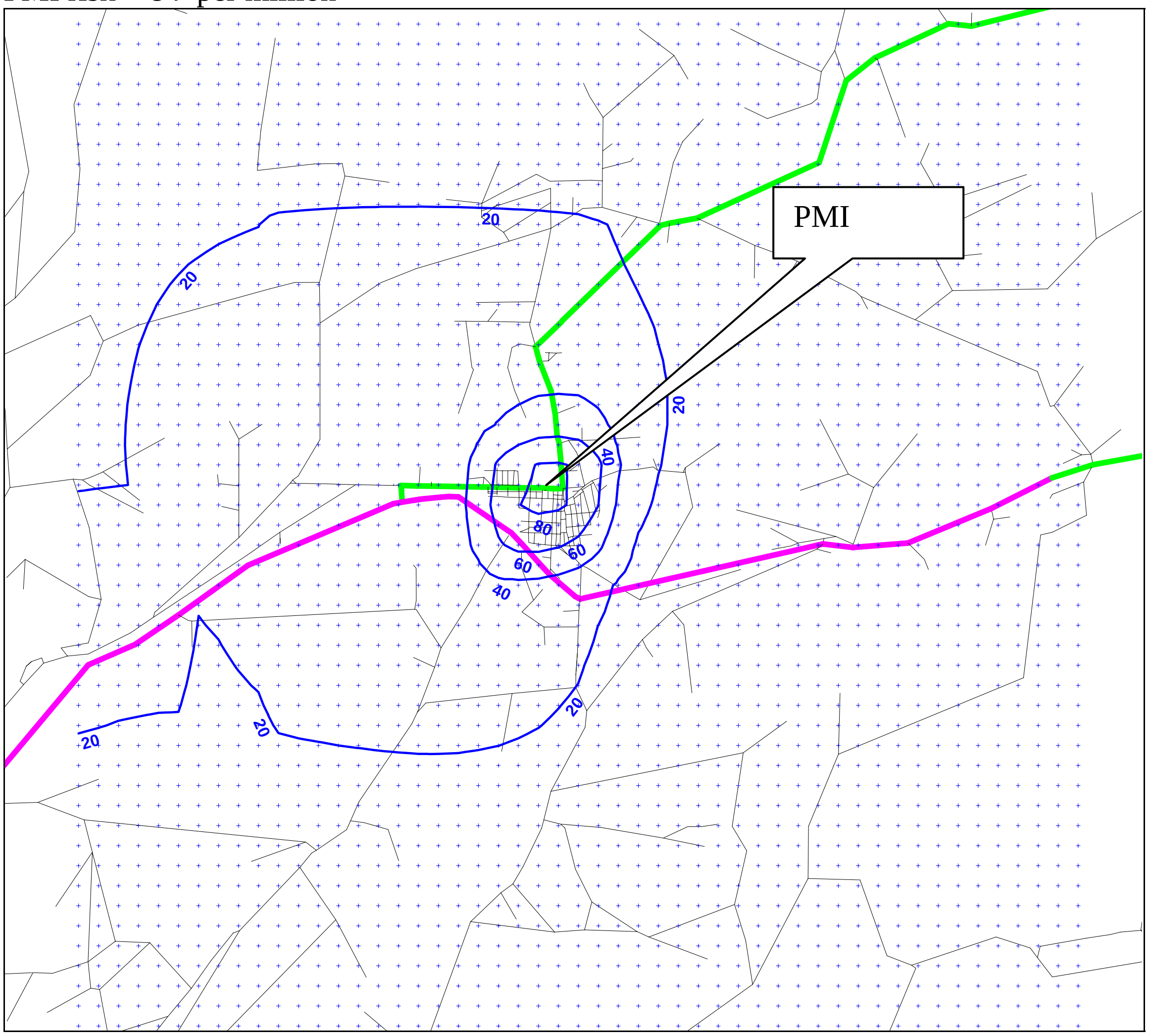
PMI risk = 71 per million



5.4.7.2.4 Wood Stoves and Fireplaces

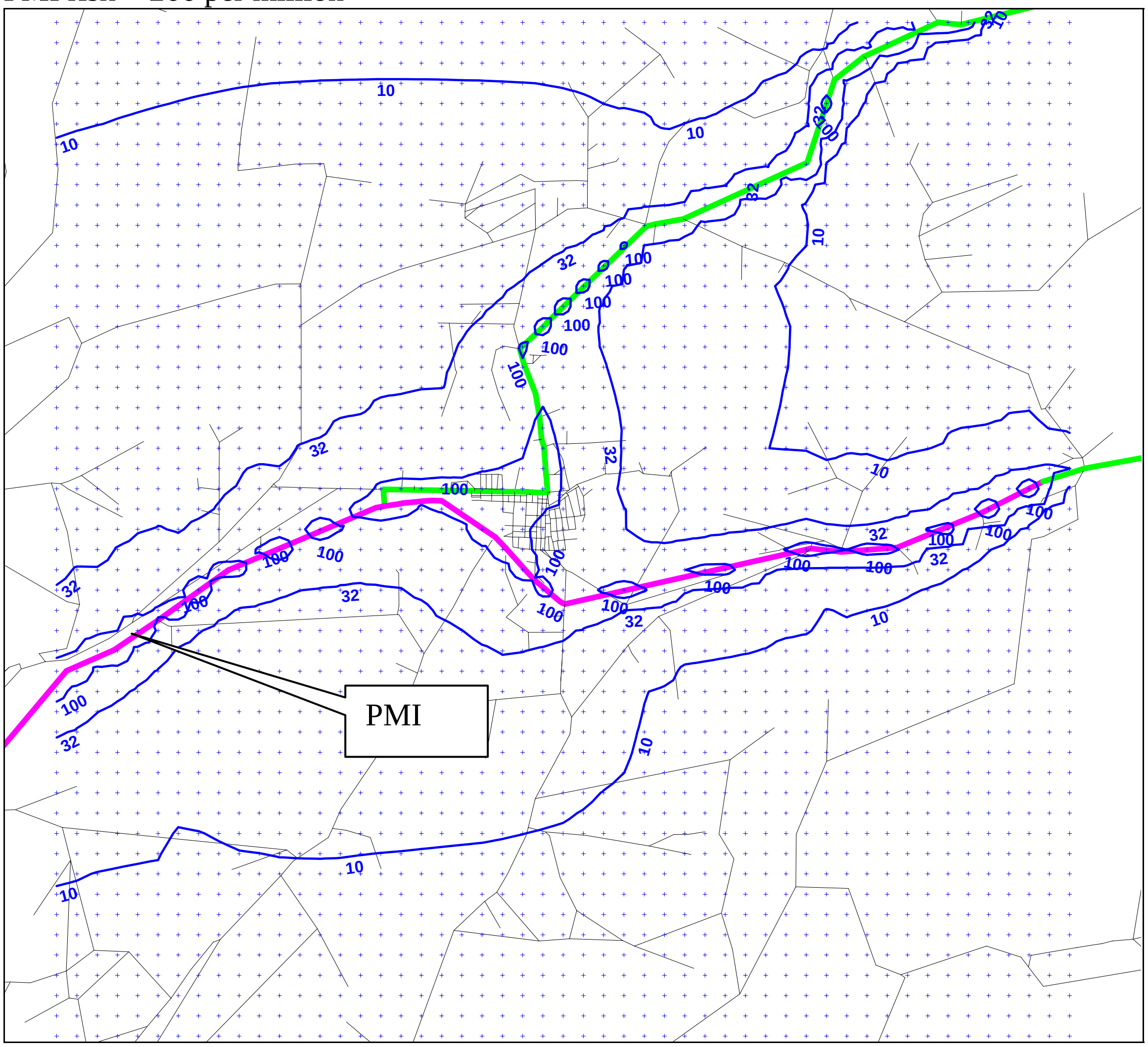
Figure 5-93. McCleary, wood stoves, cancer.

PMI risk = 84 per million



5.4.7.2.5 Total Cancer Risk

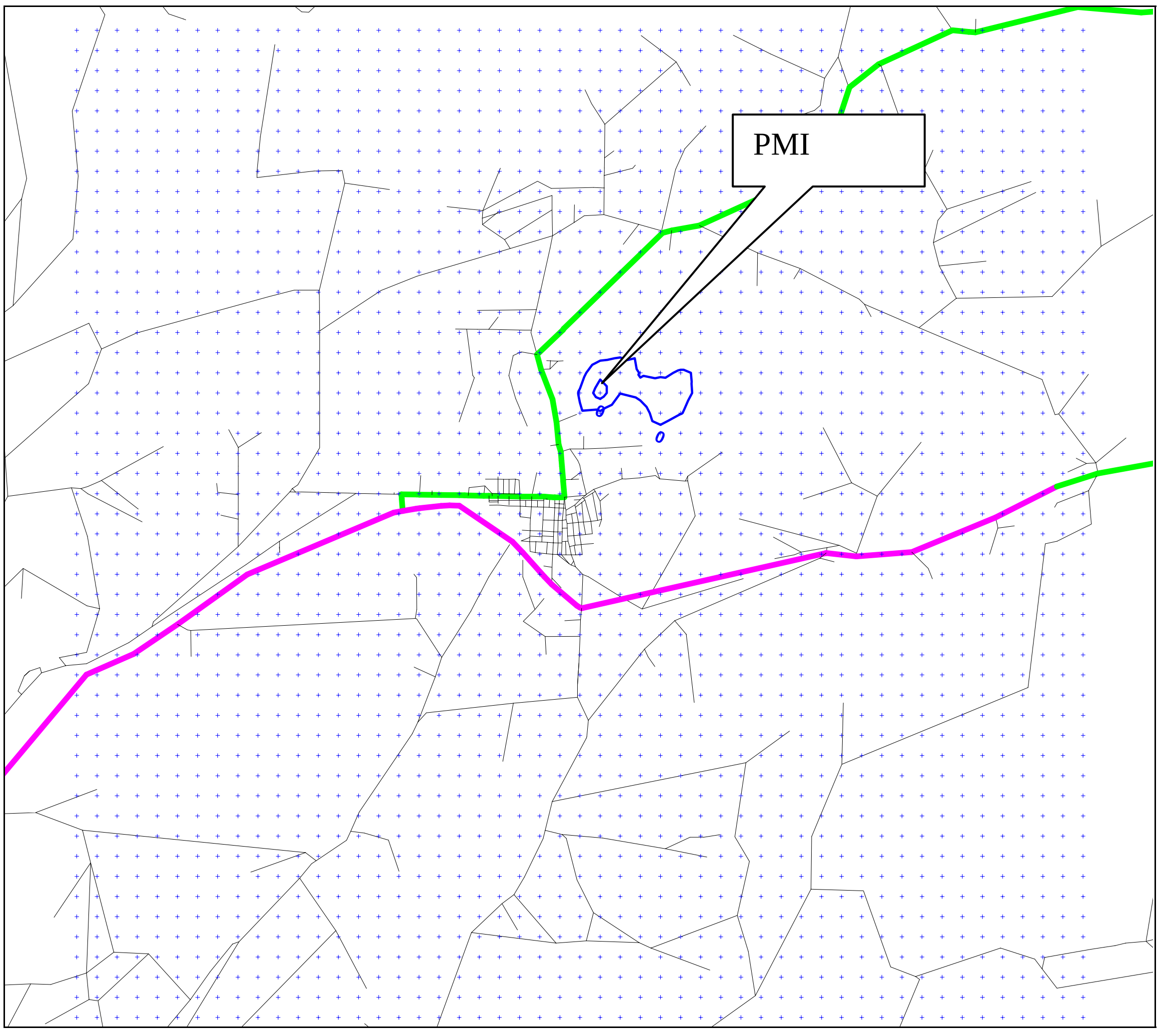
Figure 5-94. McCleary, all sources, cancer.
PMI risk = 266 per million



5.4.7.3 Chronic Non-cancer

5.4.7.3.1 Point Source (Commerical)

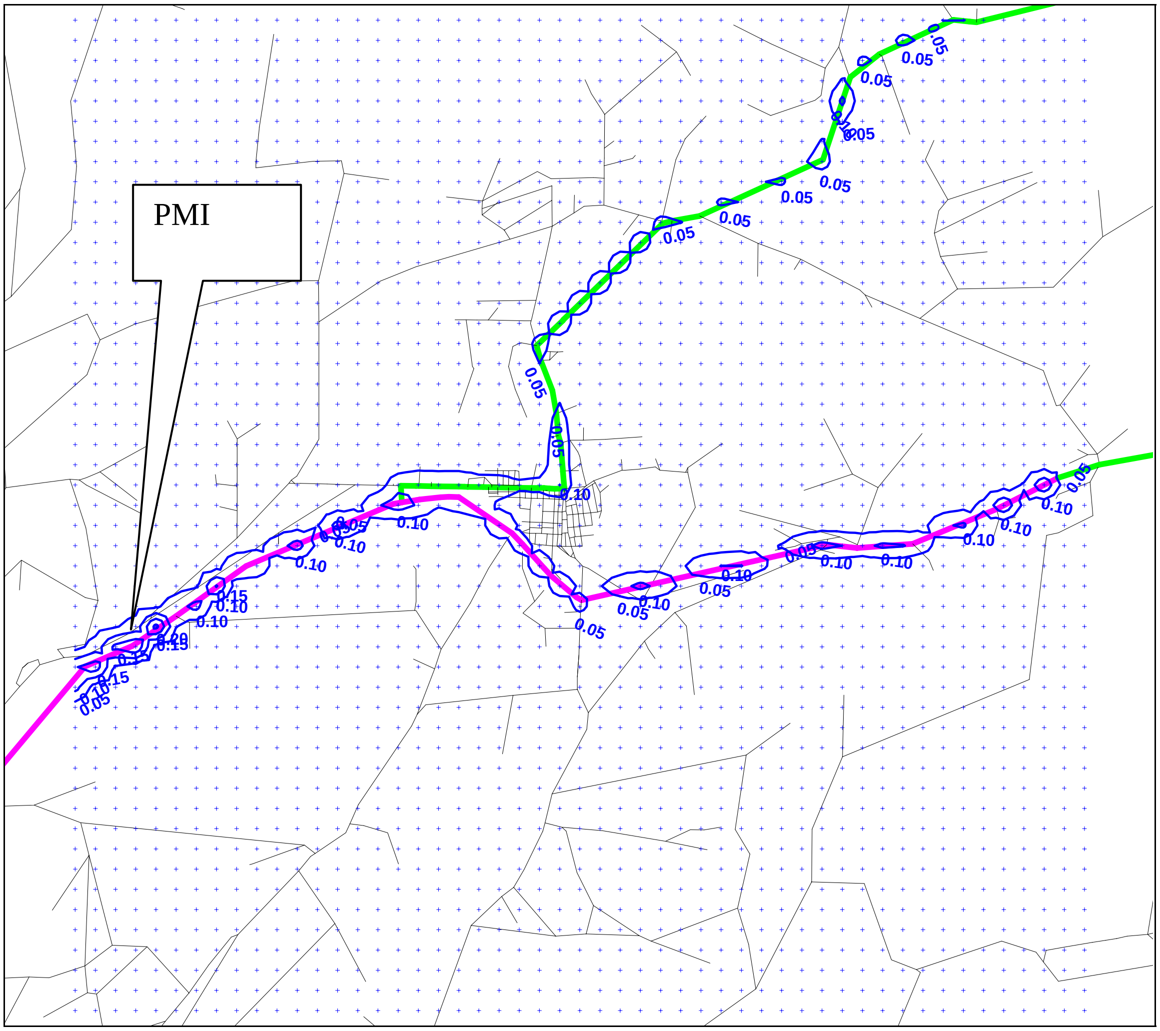
Figure 5-95. McCleary, commercial, chronic non-cancer HHI.
PMI risk = 0.12



5.4.7.3.2 Diesel On-road

Figure 5-96. McCleary, on-road diesel, chronic non-cancer HHI.

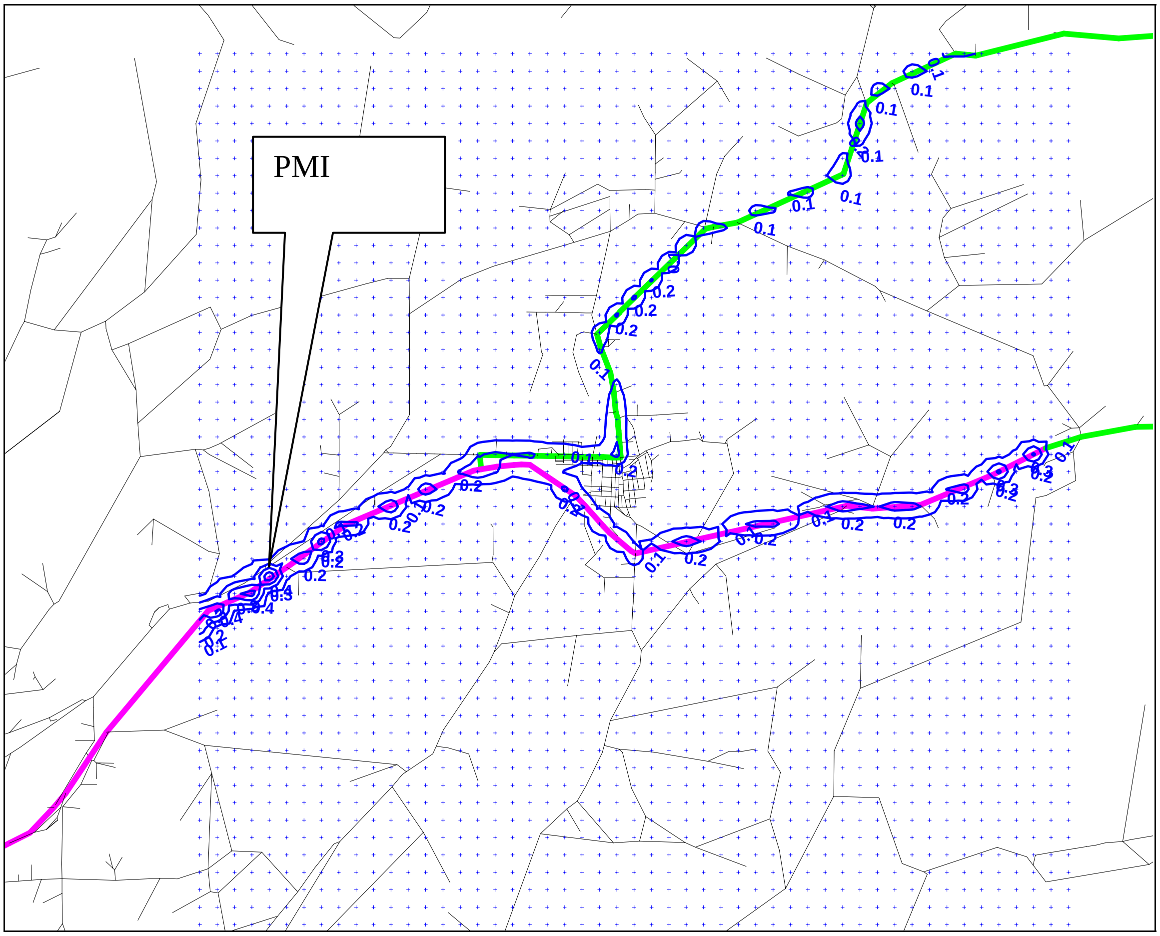
PMI risk = 0.22



5.4.7.3.3 Gasoline On-road

Figure 5-97. McCleary, on-road gasoline, chronic non-cancer HHI.

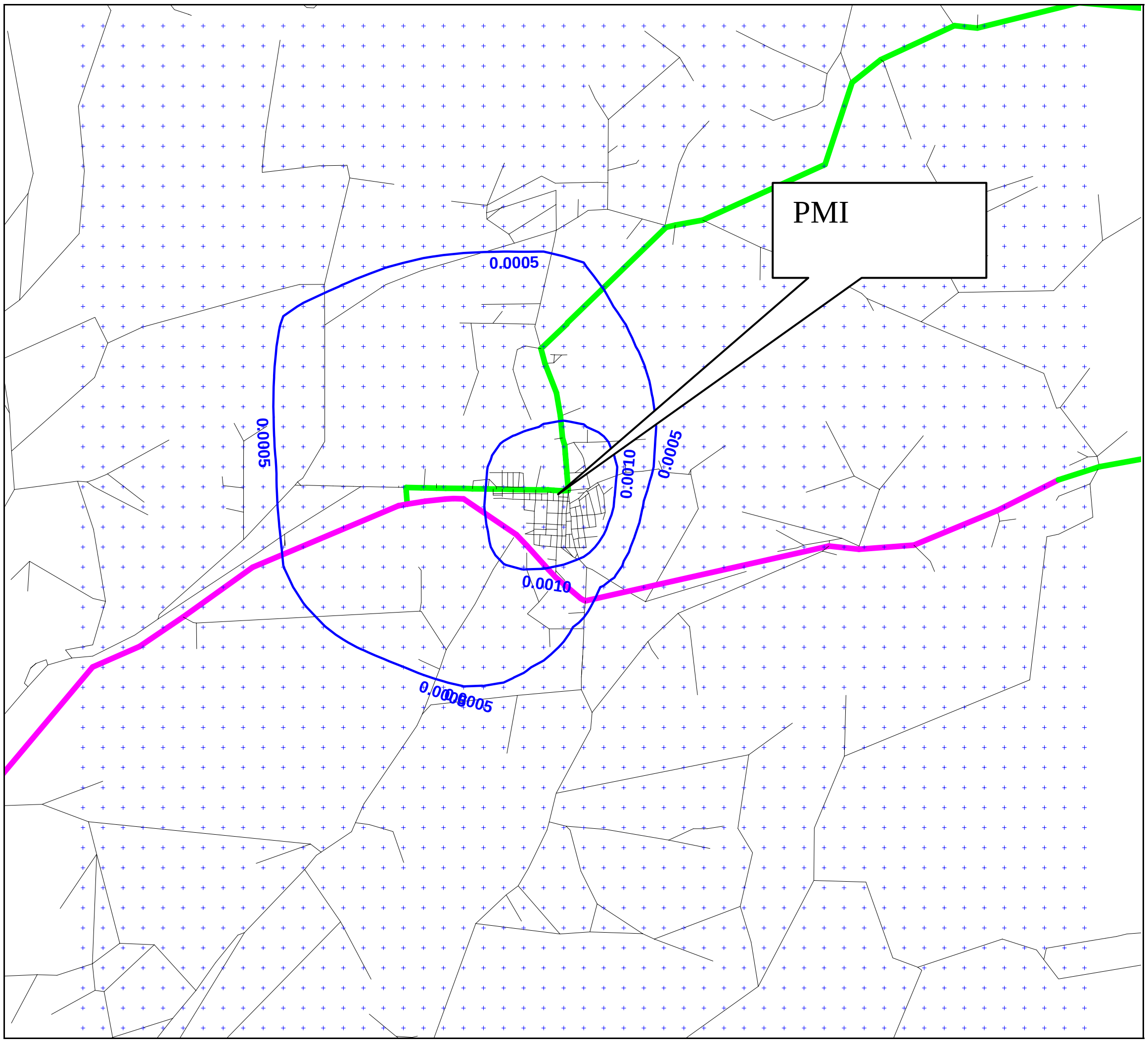
PMI risk = 0.49



5.4.7.3.4 Wood Stoves and Fireplaces

Figure 5-98. McCleary, wood stove, chronic non-cancer HHI.

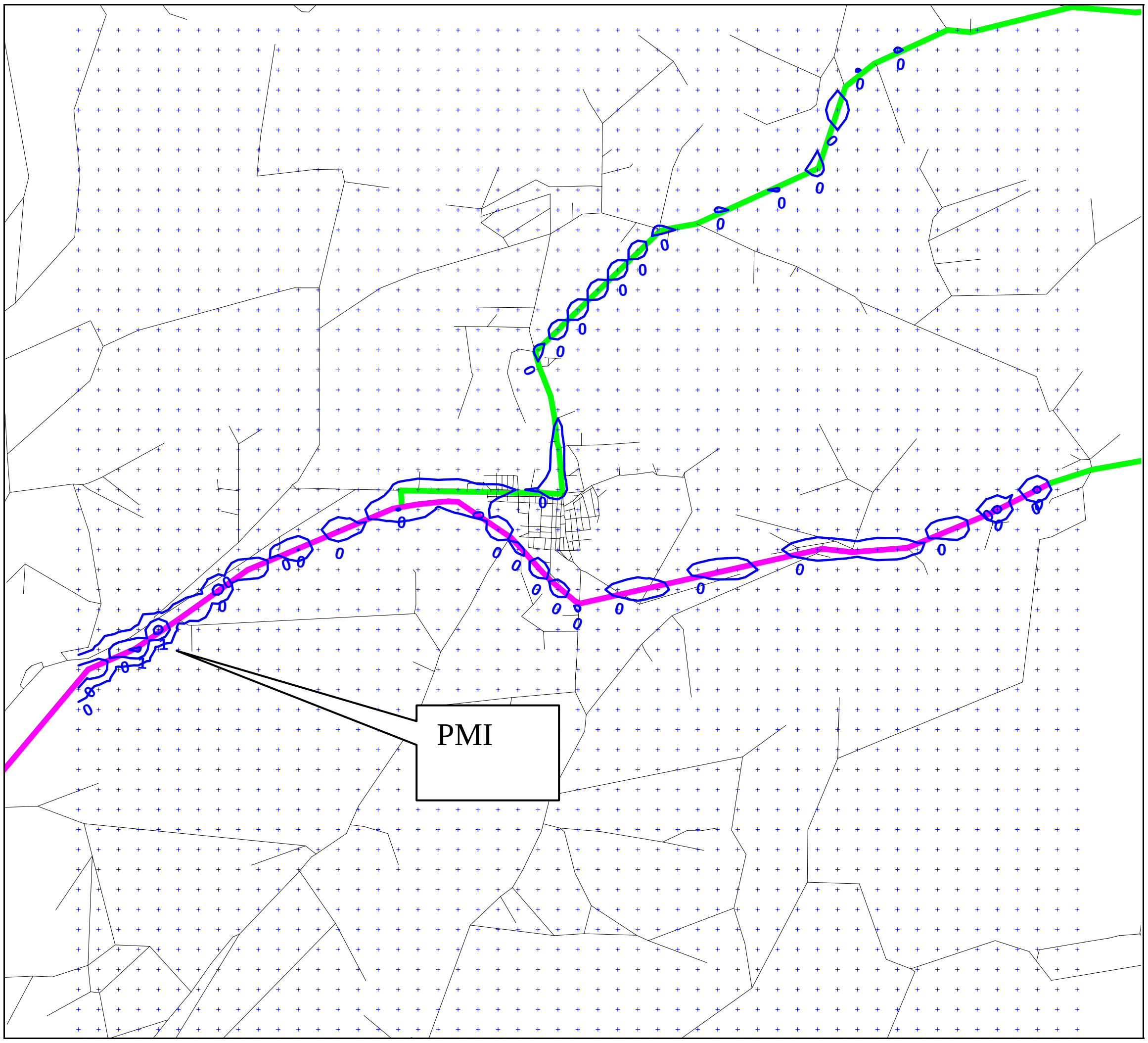
PMI risk = .0017



5.4.7.3.5 Total Chronic Risk

Figure 5-99. McCleary, all sources, chronic non-cancer HHI.

PMI risk = 0.72



5.4.8 Olympia

5.4.8.1 Summary

Figure 5-100. Olympia study area.

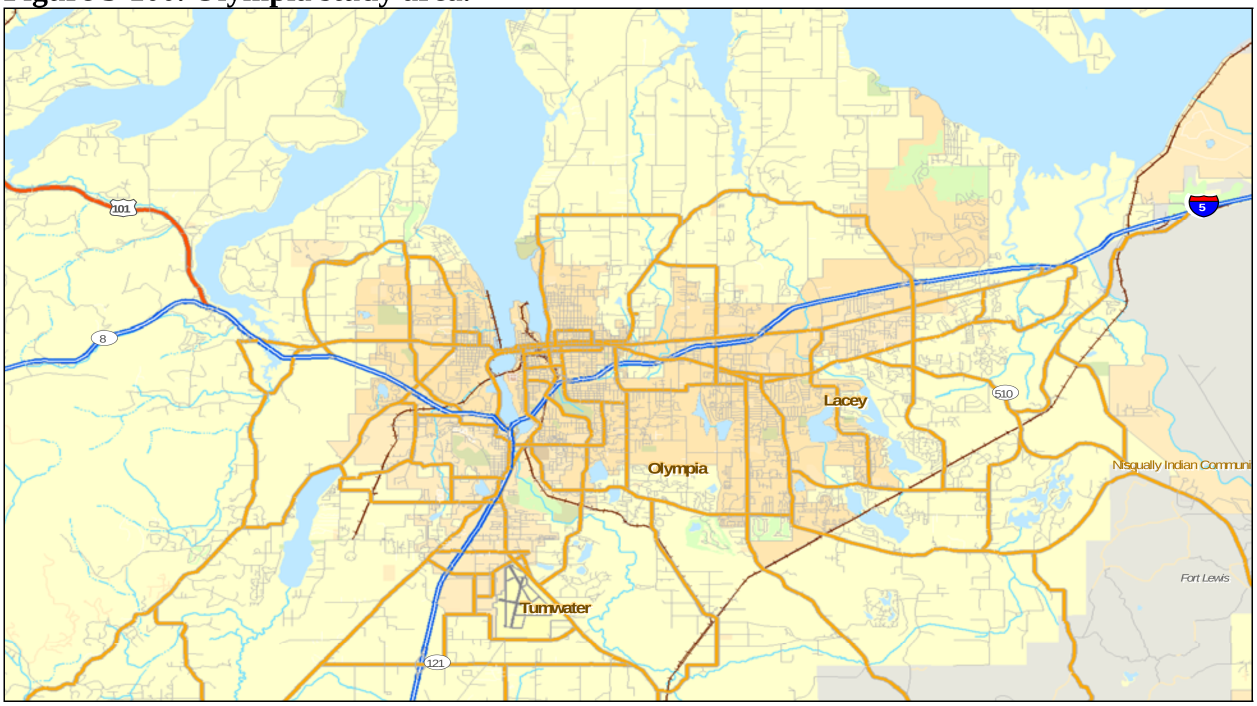


Figure 5-101. Analysis grid and locations of commercial sources. Source locations are indicated by circled X's.

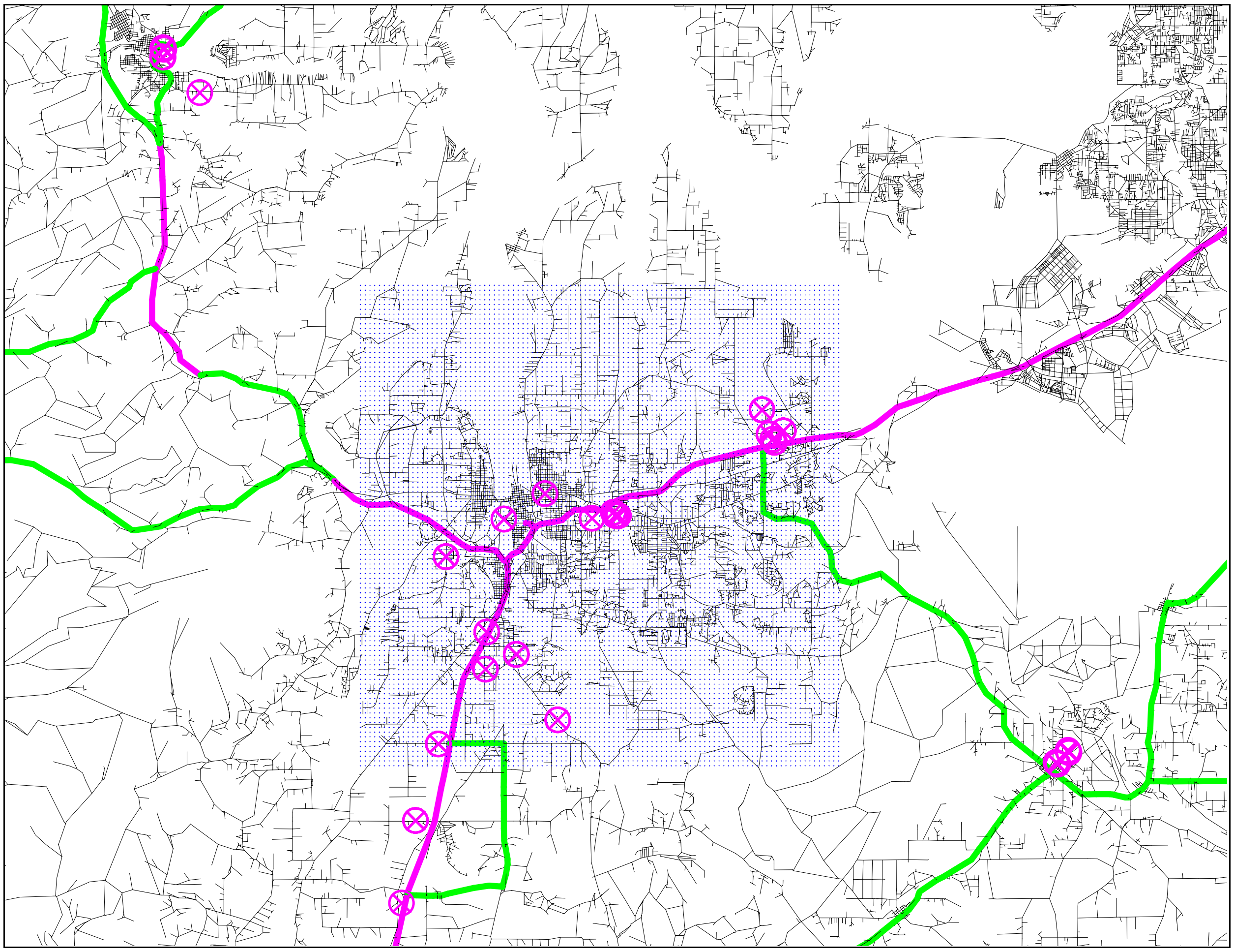


Figure 5-102. Locations of non-commercial sources. .

Small magenta squares are locations of on-road freeway, artery, collector and local road sources. Green squares are the boundaries of local road area sources. Blue squares are locations of wood stove sources.

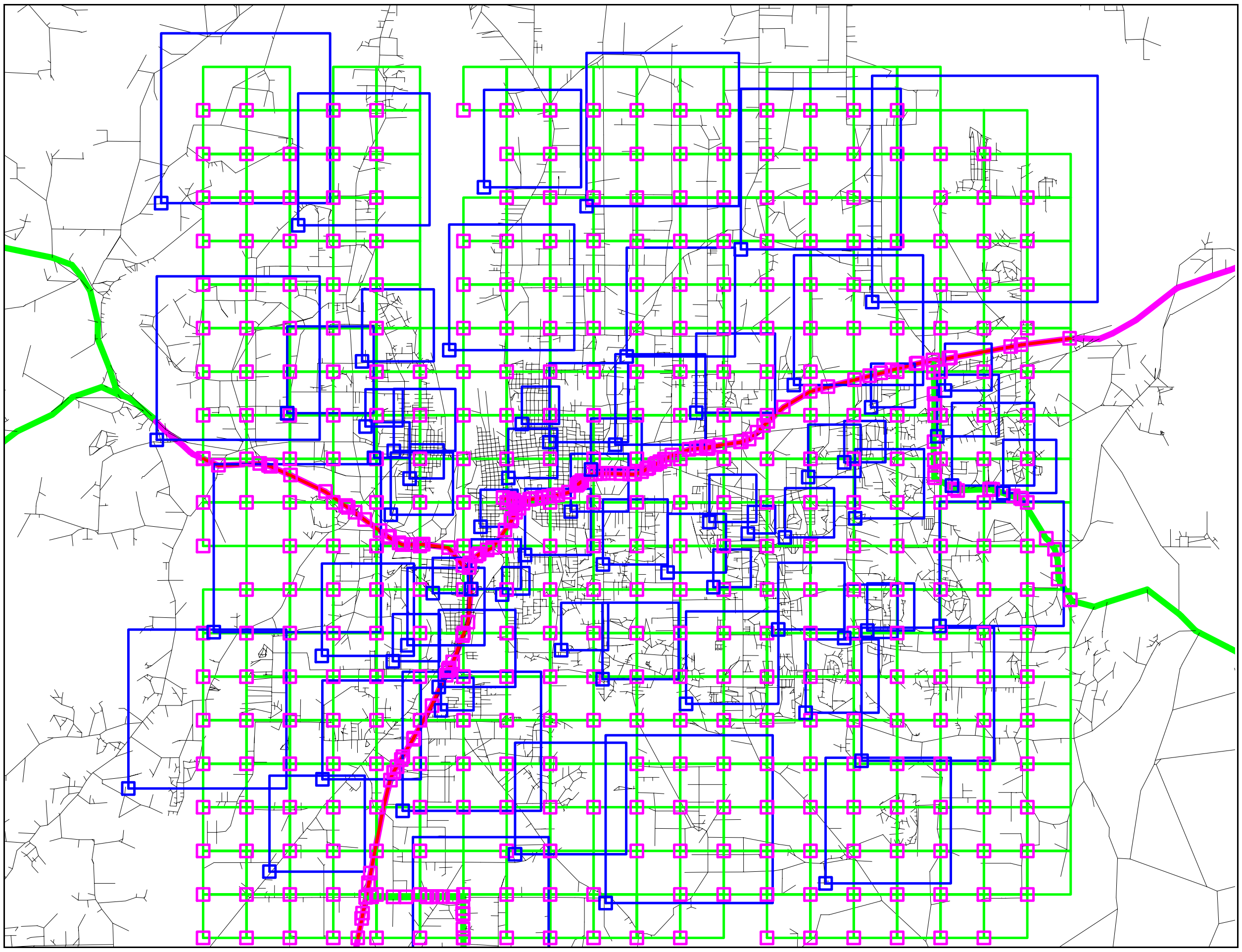


Figure 5-103. Contours of total cancer risk from all sources.

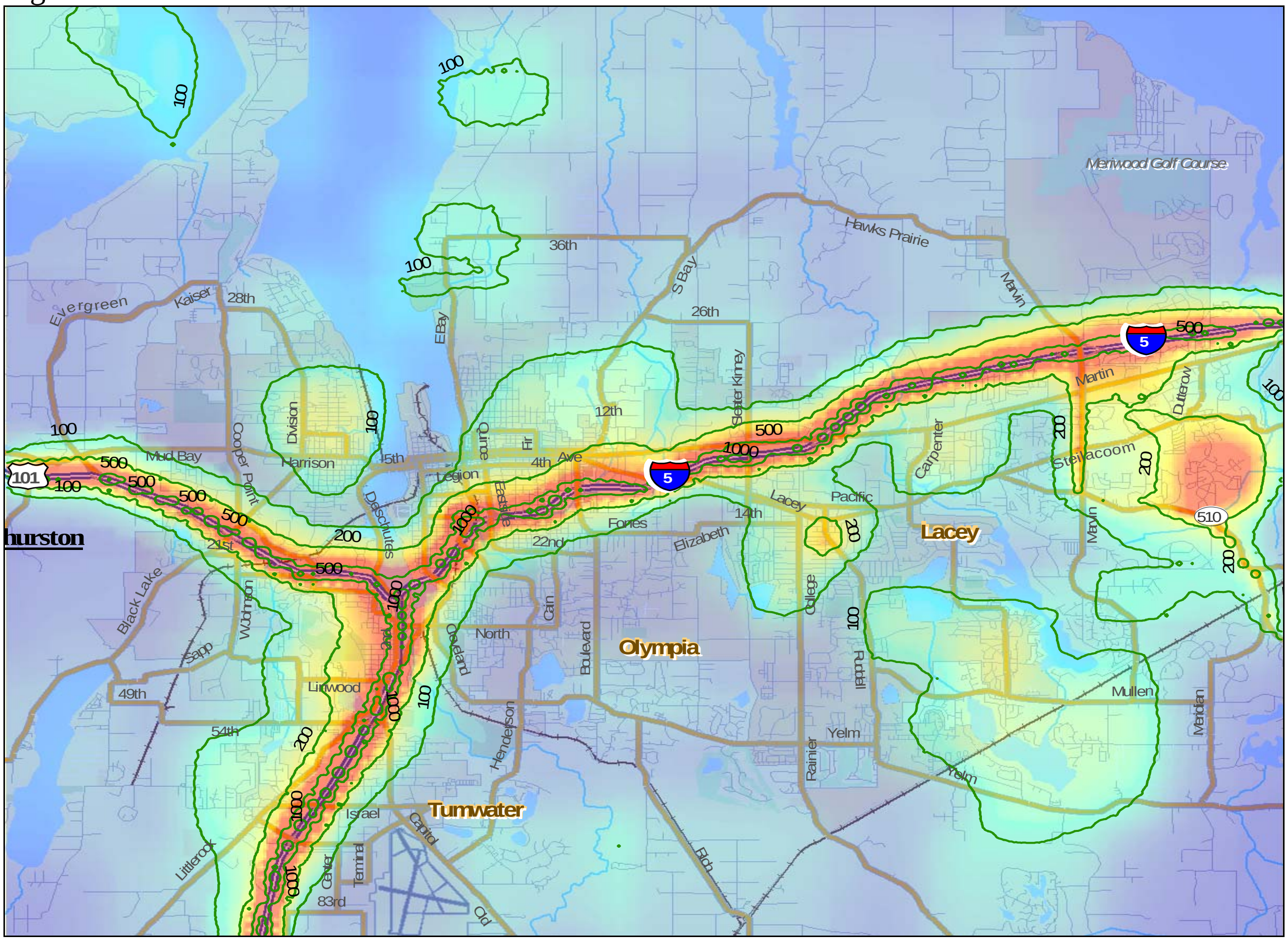
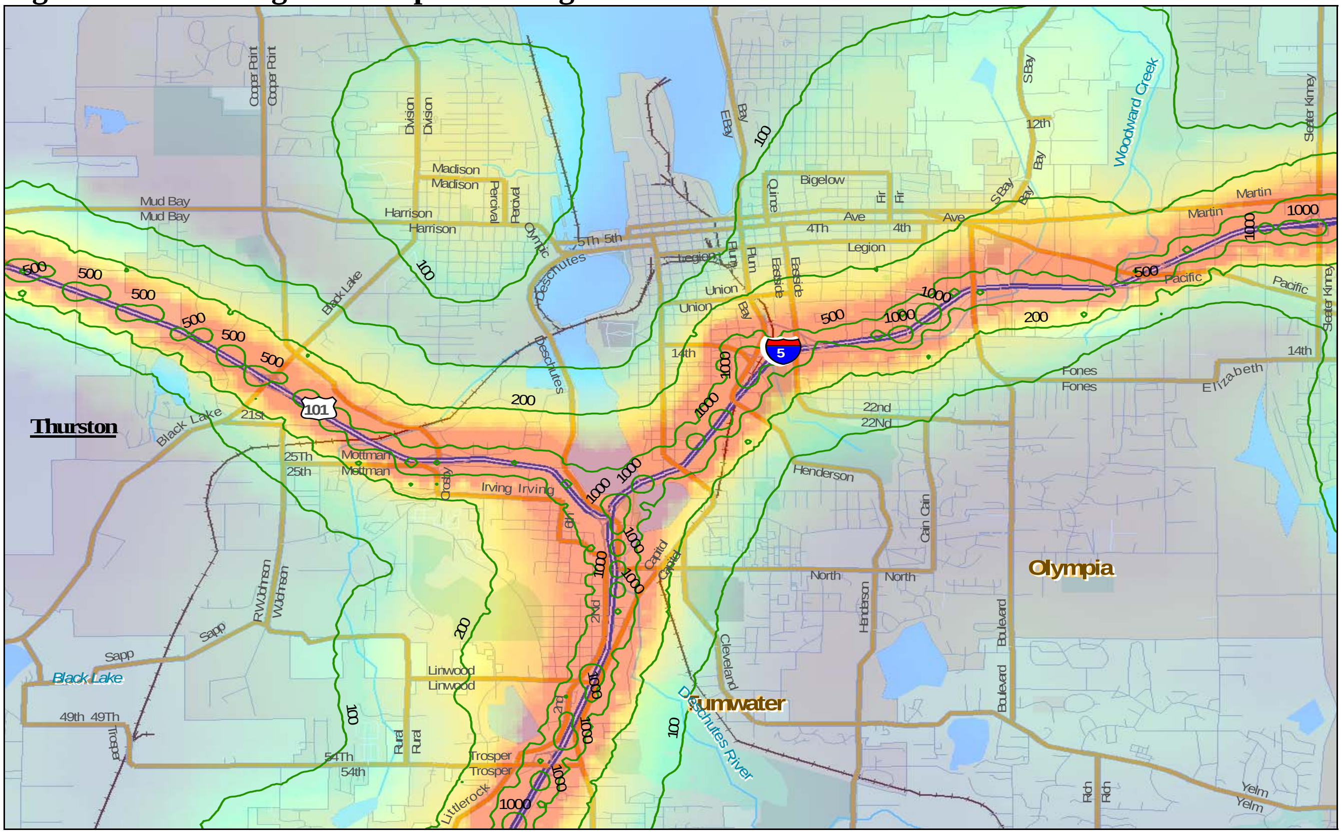


Figure 5-104. Enlargement of previous figure.



5.4.8.2 Cancer

5.4.8.2.1 Point Source (Commerical)

Figure 5-105. Commercial sources included in this study.

Facility	***Stack***	***UTME***	***UTMN***
		meters	***meters***
AMTECH CORPORATION	stack 16712	530172	5199081
AMTECH CORPORATION	stack 16711	530158	5199062
COLUMBIA BEVERAGE COMPANY	stack 1642	504582	5207702
CROWN CORK SEAL CO INC	stack 10004	511723	5209438
COLUMBIA BEVERAGE COMPANY	stack 1641	504582	5207702
AMTECH CORPORATION	stack 16713	530177	5199069
CROWN CORK SEAL CO INC	stack 10009	511800	5209408
CROWN CORK SEAL CO INC	stack 10001	511662	5209412
ALBANY INTERNATIONAL	stack 1031	506286	5204562
THURSTON COUNTY WASTE AND RECOVERY CENTER - Landfill	stack 1002	518092	5212800
CROWN CORK SEAL CO INC	stack 10010	511769	5209404
THURSTON COUNTY WASTE AND RECOVERY CENTER - Landfill	stack 1001	518247	5212584
SIMPSON TIMBER CO	stack 678	492754	5228492
CRAGER PREHUNG DOOR	stack 331	494283	5227018
OLYMPIC PANEL PRODUCTS LLC	stack 675	492785	5228823
OLYMPIC PANEL PRODUCTS LLC	stack 6715	492731	5228865
OLYMPIC PANEL PRODUCTS LLC	stack 6711	492723	5228508
CENTRAL STEAM PLANT	stack 1341	507002	5209264
DOORS UNLIMITED	stack 2491	510690	5209302
LAKESIDE INDUSTRIES - LACEY	stack 621	518322	5212462
SHELL OIL PRODUCTS US TUMWATER TERMINAL	stack 6371	506234	5203016
DART CONTAINER CORP OF WASHINGTON	stack 592	507525	5203631
DART CONTAINER CORP OF WASHINGTON	stack 591	507525	5203631
LASCO BATHWARE	stack 56	530602	5199612
LASCO BATHWARE	stack 55	530637	5199541
LASCO BATHWARE	stack 53	530642	5199561
LASCO BATHWARE	stack 52	530596	5199638
OLYMPIC PAINTING	stack 1721	502723	5193278
LAKESIDE INDUSTRIES - OLD HWY 99 OLY	stack 3821	509257	5200906
AMTECH CORPORATION	stack 1672	530092	5199133
WILDER CONSTRUCTION CO	stack 7151	503307	5196718
OLYMPIC PANEL PRODUCTS LLC	stack 6710	492762	5228892
NUTRIOM LLC	stack 2471	517801	5213813
OLYMPIAN	stack 7891	508722	5210321
RT LONDON - NORSE	stack 2432	518689	5212941
RT LONDON - NORSE	stack 2431	518689	5212941
GEORGIA PACIFIC CORP	stack 1791	511581	5209548
NUTRIOM LLC	stack 2472	517801	5213813
NORTHWEST PIPELINE CORPORATION	stack 6921	504261	5199907

Table 5-30. Dominant chemicals contributing to cancer risk, commercial sources.

CAS	POLLUTANT NAME	INHAL	DERM	SOIL	TOTAL
107131	Acrylonitrile	4.69E-05	0.00E+00	0.00E+00	4.69E-05
75014	Vinyl chloride	1.75E-05	0.00E+00	0.00E+00	1.75E-05
127184	Perchloroethylene {Tetrachloroethene}	1.83E-06	0.00E+00	0.00E+00	1.83E-06

Table 5-31. Emissions of dominant chemicals.

Acrylonitrile

Facility	Annual EMS (lbs/yr)
THURSTON COUNTY WASTE AND RECOVERY CENTER - Landfill	71

Vinyl chloride

Facility	Annual EMS (lbs/yr)
THURSTON COUNTY WASTE AND RECOVERY CENTER - Landfill	98
SIMPSON TIMBER CO	28

Perchloroethylene

Facility	Annual EMS (lbs/yr)
THURSTON COUNTY WASTE AND RECOVERY CENTER - Landfill	132

Figure 5-106.Olympia, commercial, cancer.
PMI risk = 67 per million

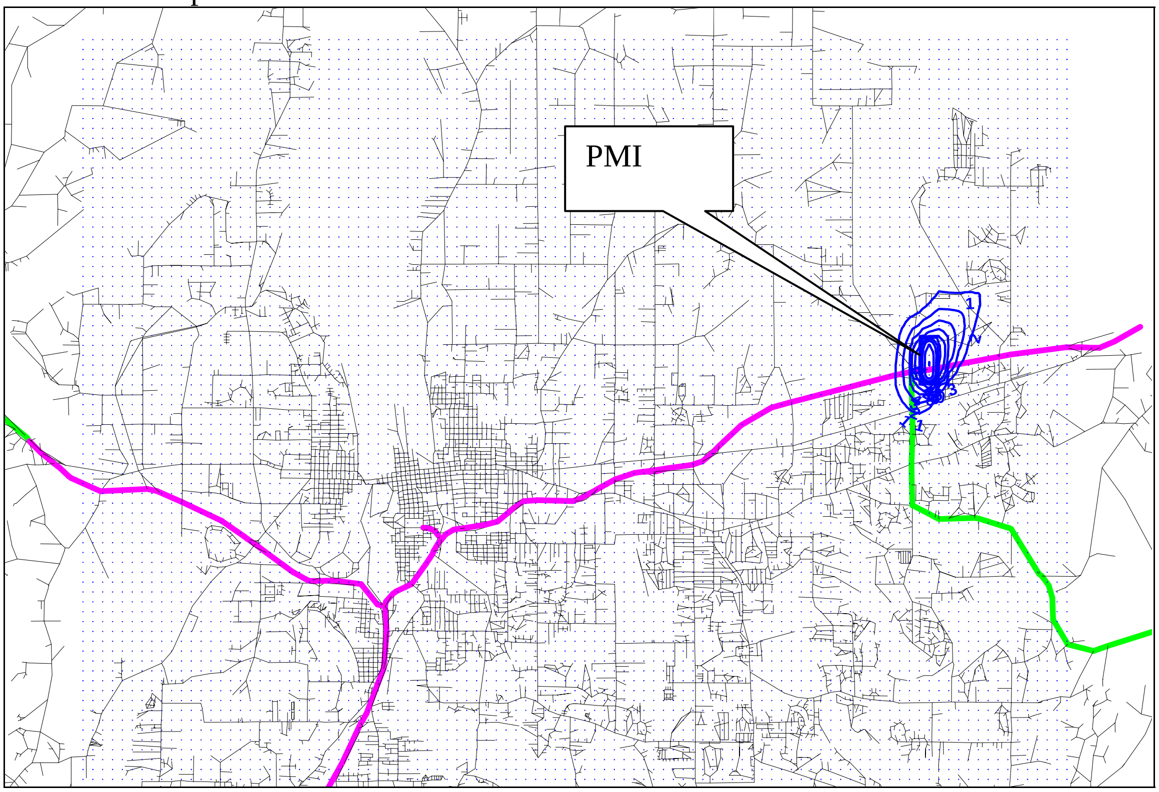
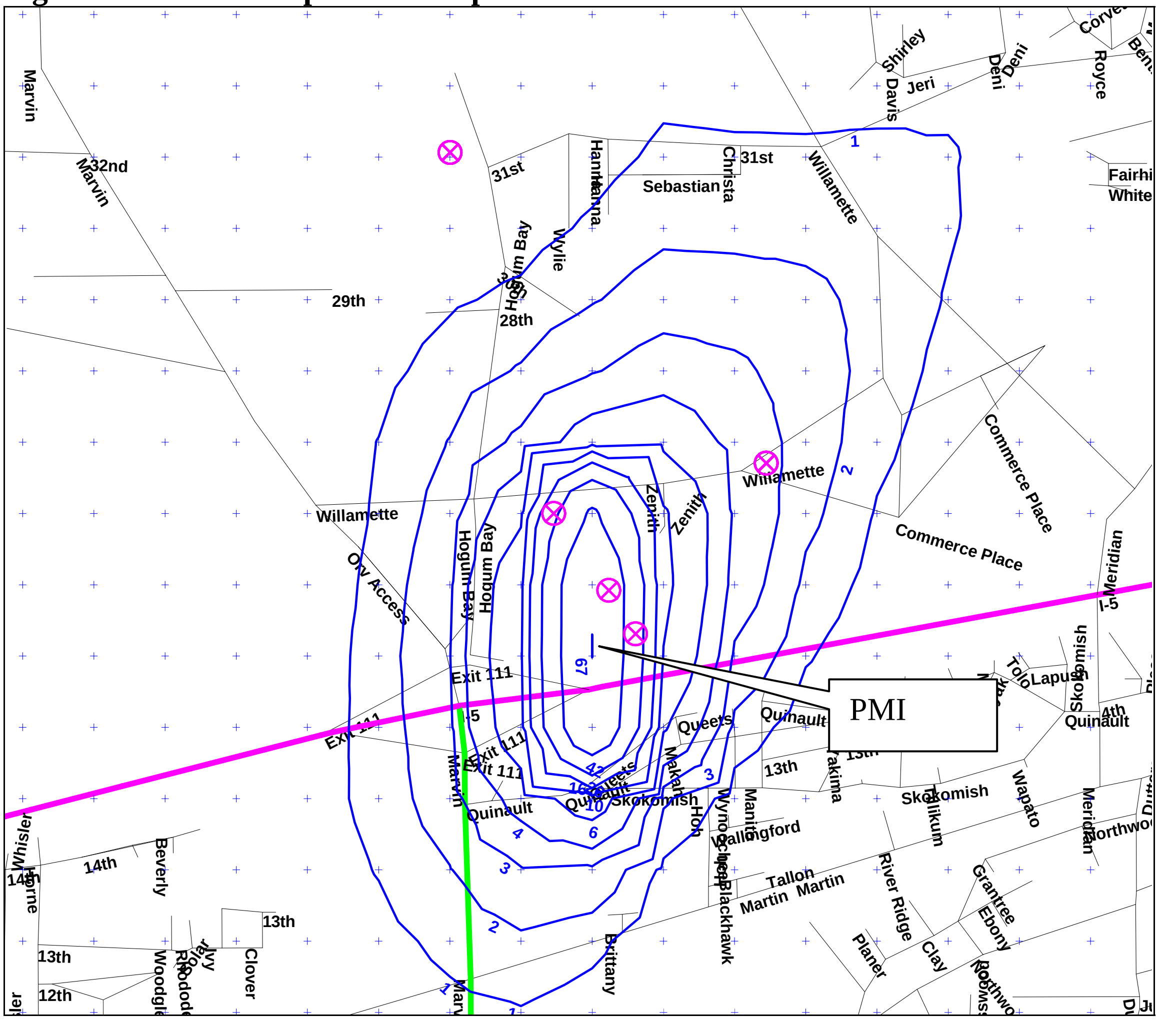


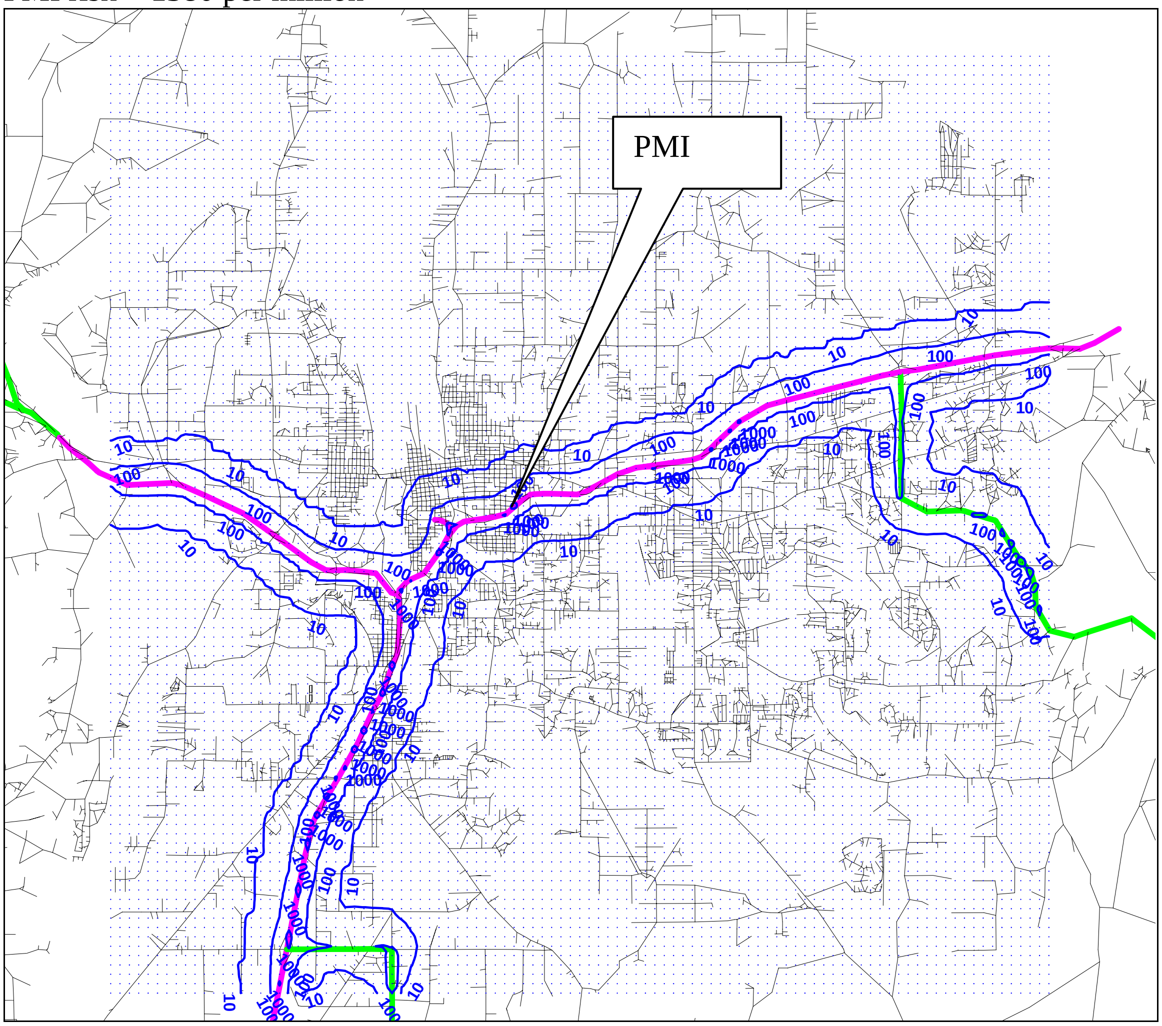
Figure 5-107. Inset of previous map.



5.4.8.2.2 Diesel On-road

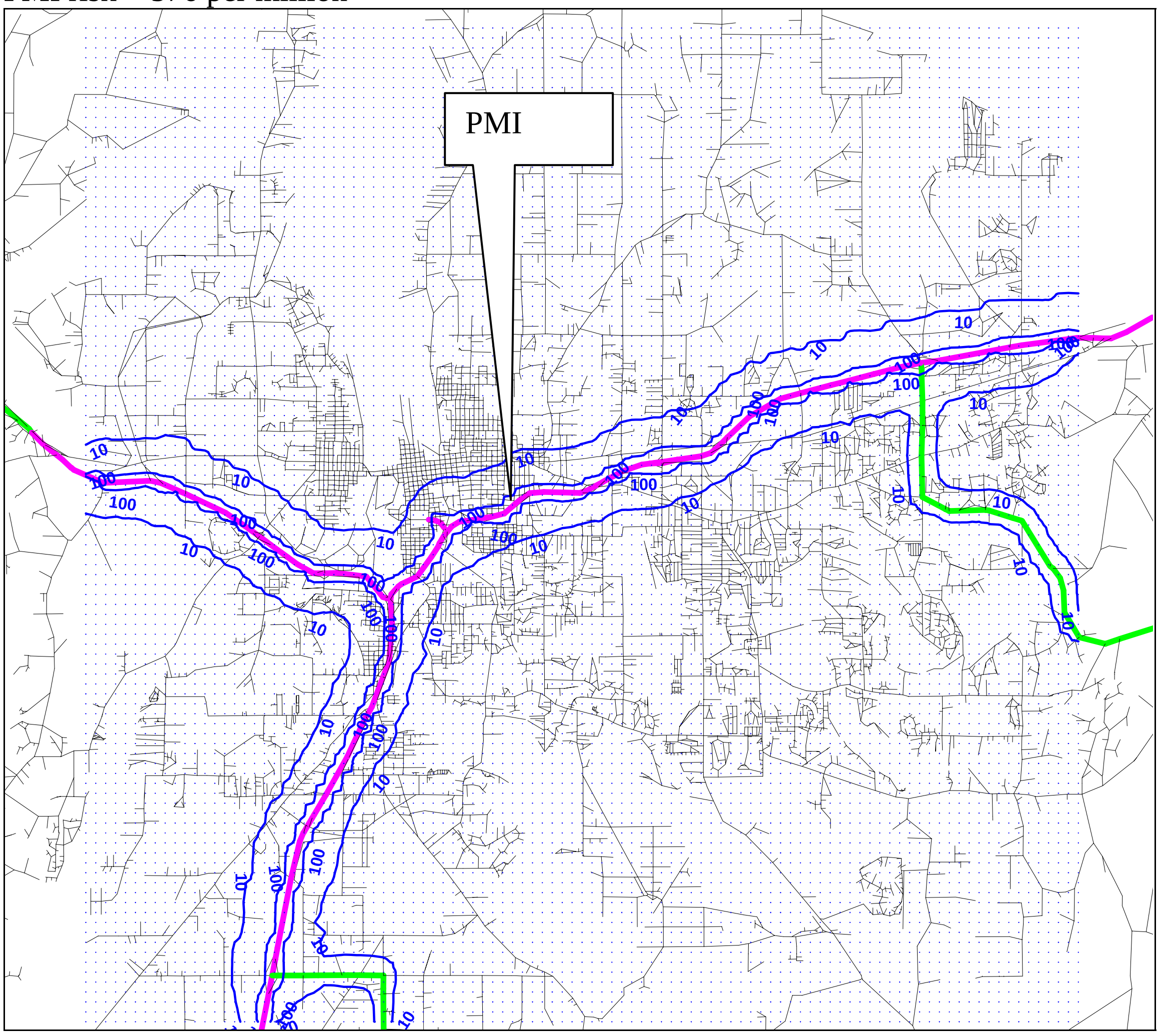
Figure 5-108. Olympia, on-=road diesel, cancer.

PMI risk = 1380 per million



5.4.8.2.3 Gasoline On-road

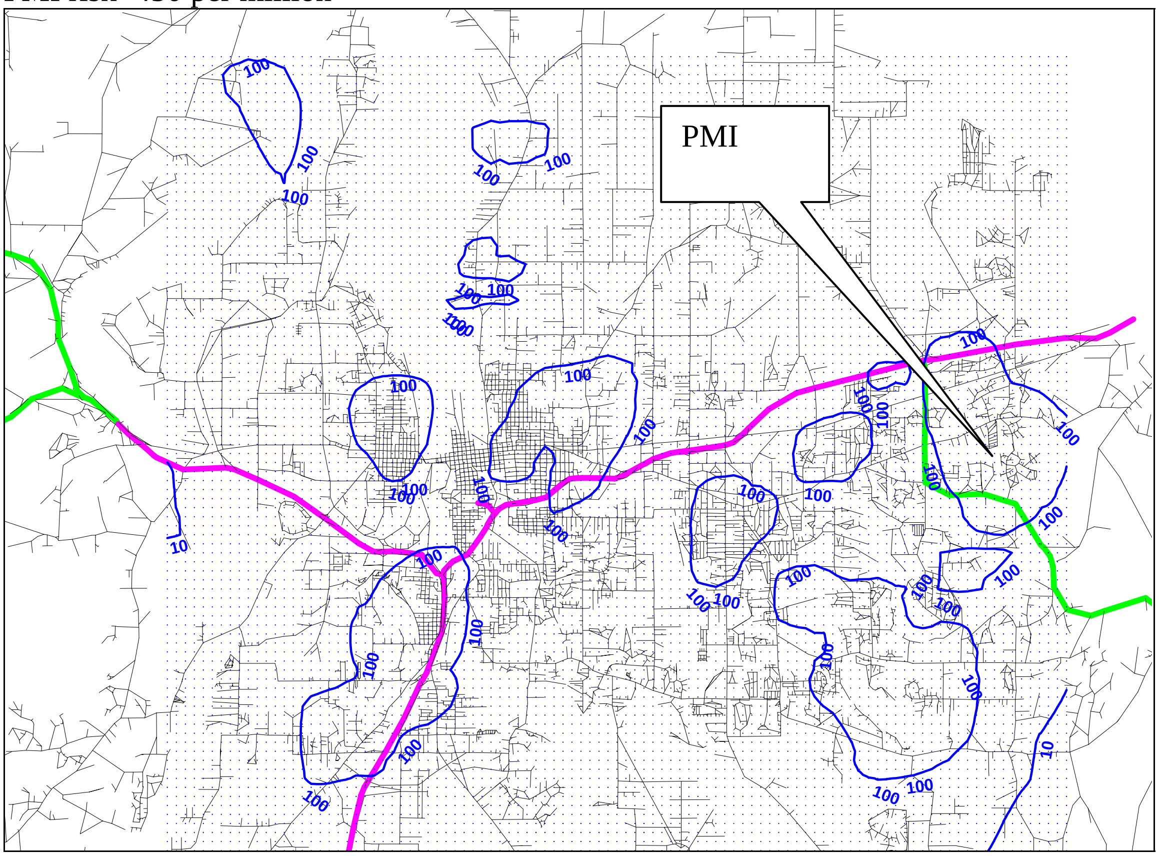
Figure 5-109. Olympia, on-road gasoline, cancer.
PMI risk = 576 per million



5.4.8.2.4 Wood Stoves and Fireplaces

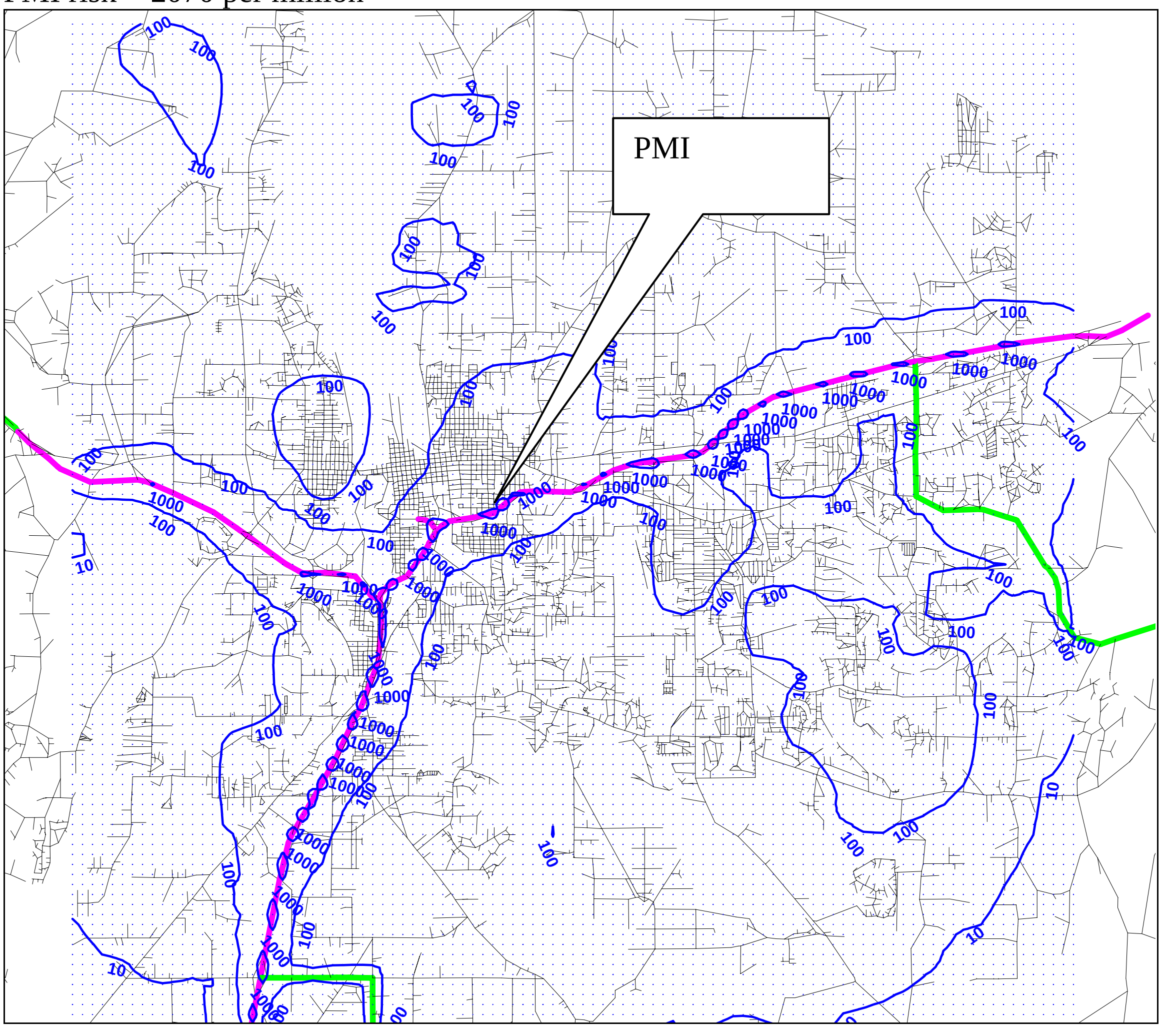
Figure 5-110. Olympia, wood stoves, cancer.

PMI risk=450 per million



5.4.8.2.5 Total Cancer Risk

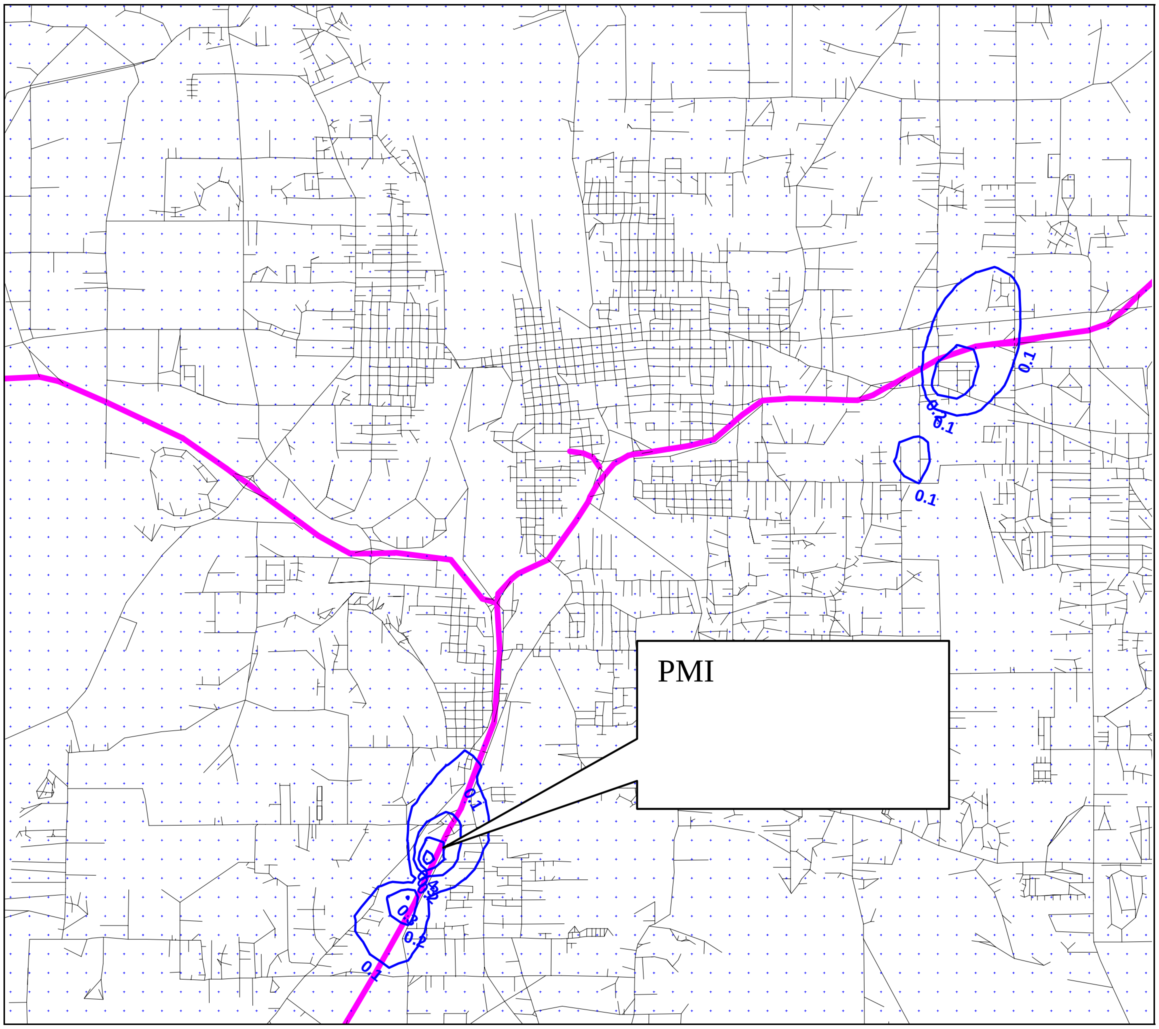
Figure 5-111. Olympia, all sources, cancer.
PMI risk = 2070 per million



5.4.8.3 Chronic Non-cancer

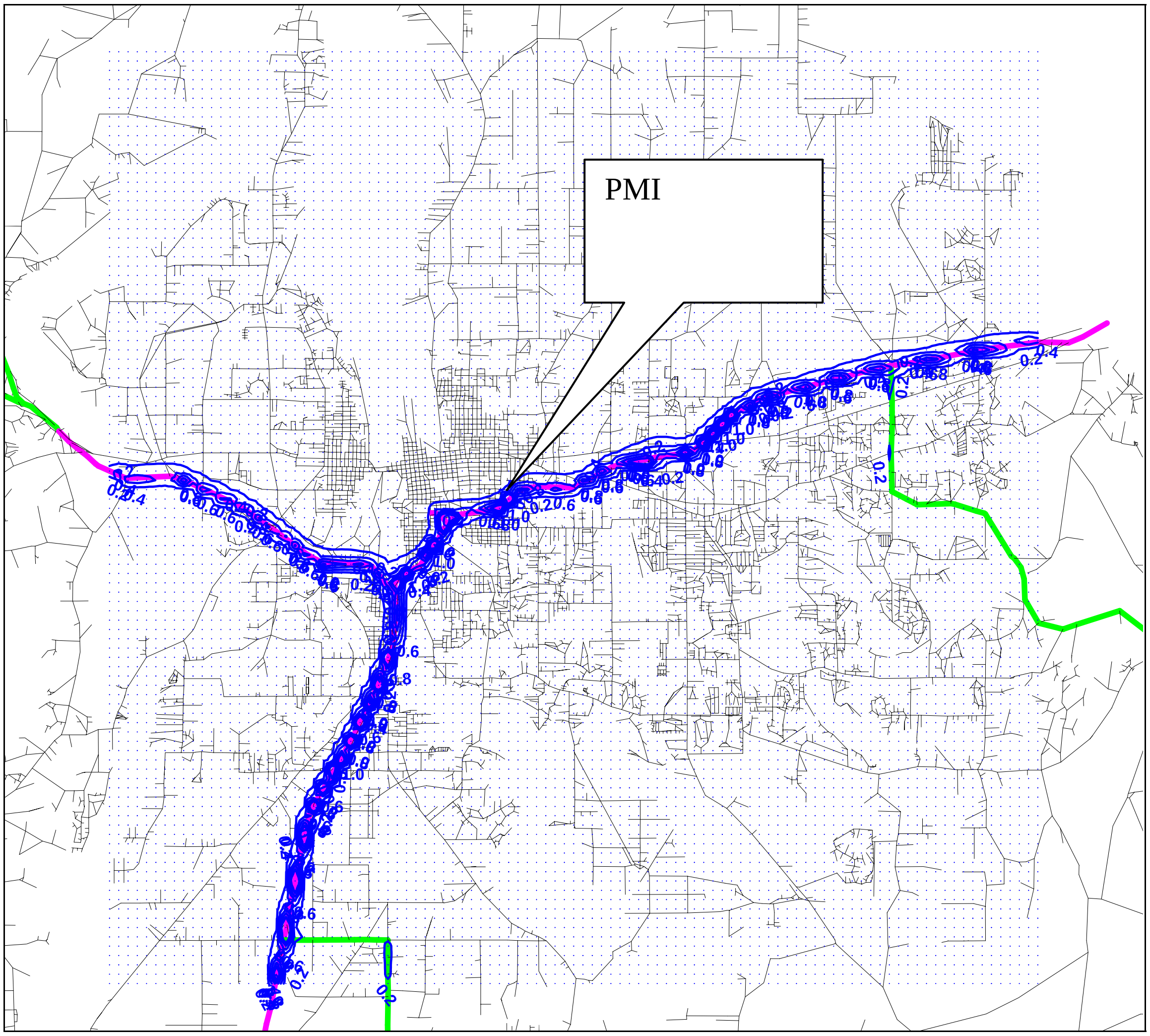
5.4.8.3.1 Point Source (Commerical)

Figure 5-112. Olympia, commercial, chronic non-cancer HHI.
PMI risk = 0.47



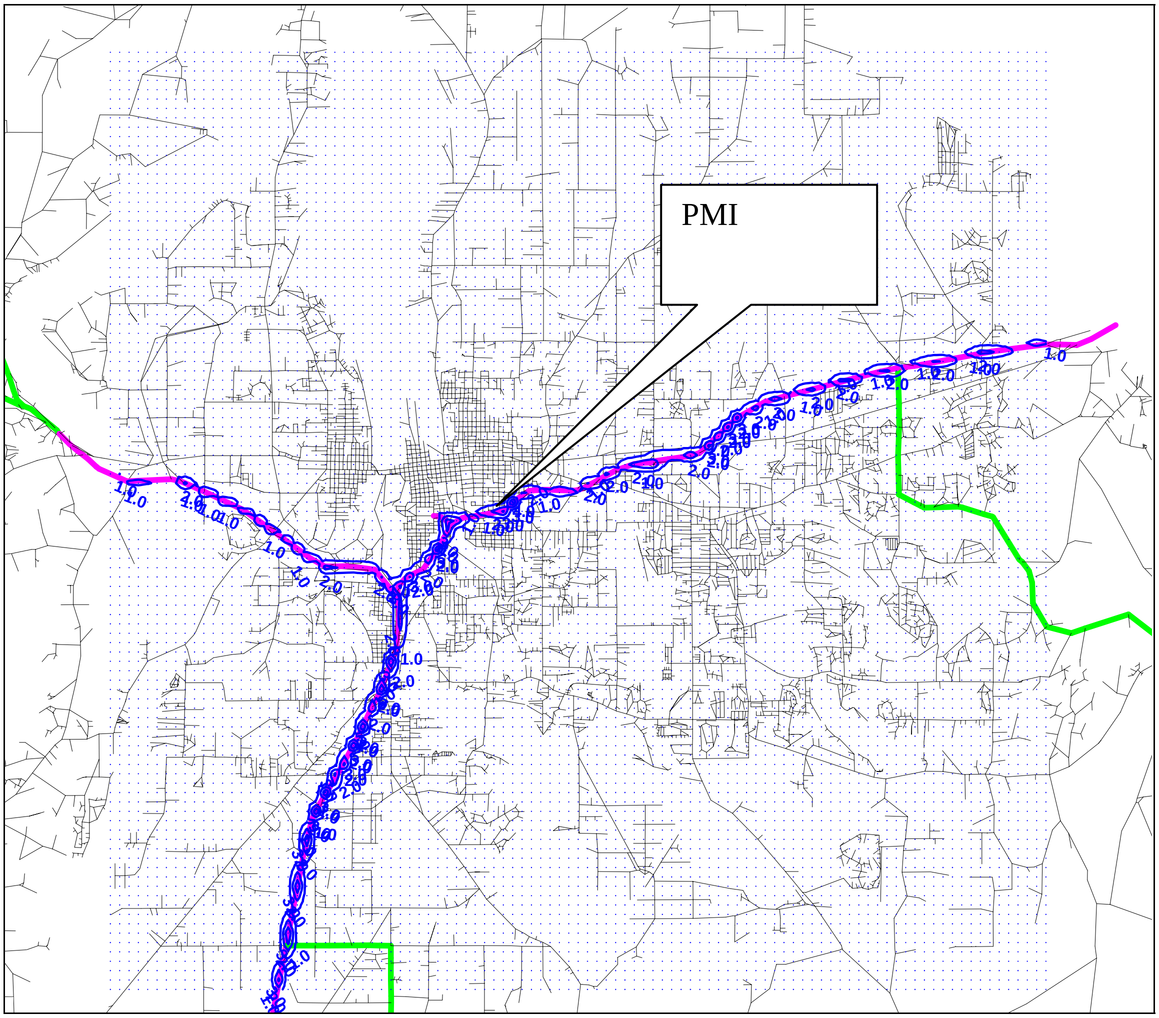
5.4.8.3.2 Diesel On-road

Figure 5-113. Olympia, on-road diesel, chronic non-cancer HHI.
PMI risk = 1.76



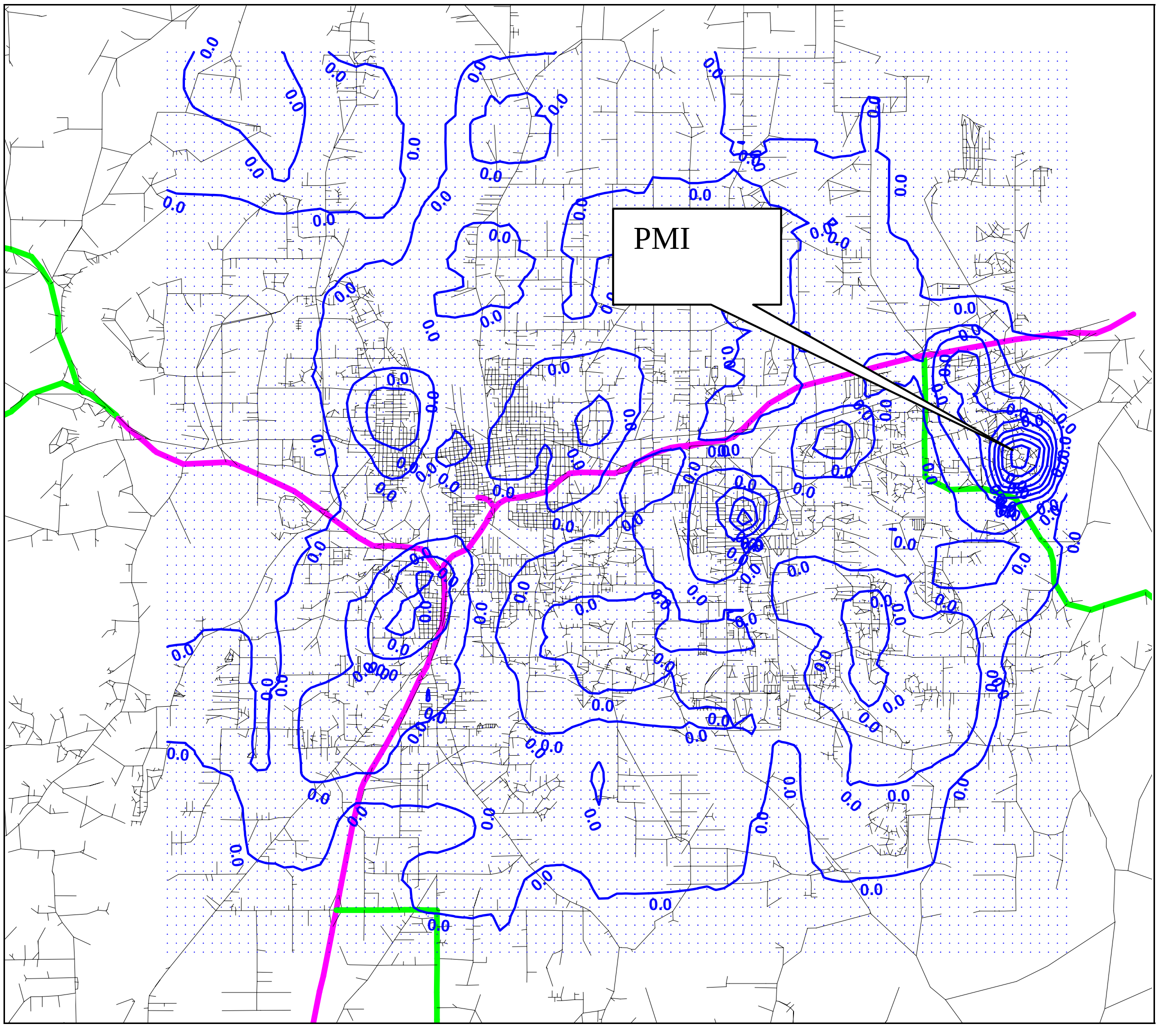
5.4.8.3.3 Gasoline On-road

Figure 5-114. Olympia, on-road gasoline, chronic non-cancer HHI.
PMI risk = 4.01



5.4.8.3.4 Wood Stoves and Fireplaces

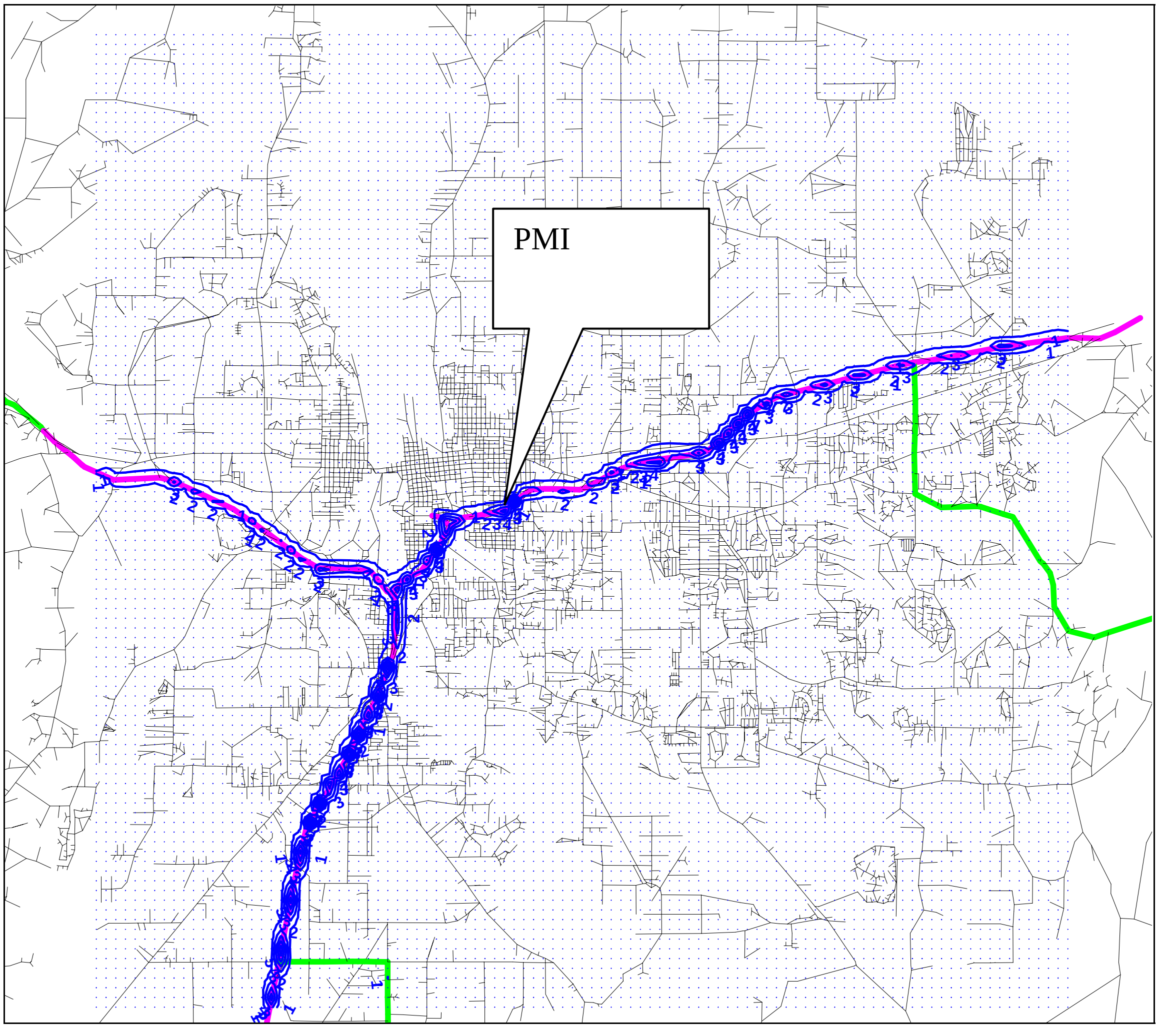
Figure 5-115. Olympia, wood stoves, chronic non-cancer HHI.
PMI risk = 0.0094



5.4.8.3.5 Total Chronic Risk

Figure 5-116. Olympia, all sources, Chronic non-cancer HHI.

PMI risk = 5.96



5.4.9 Yelm

5.4.9.1 Summary

Figure 5-117. Yelm study area.

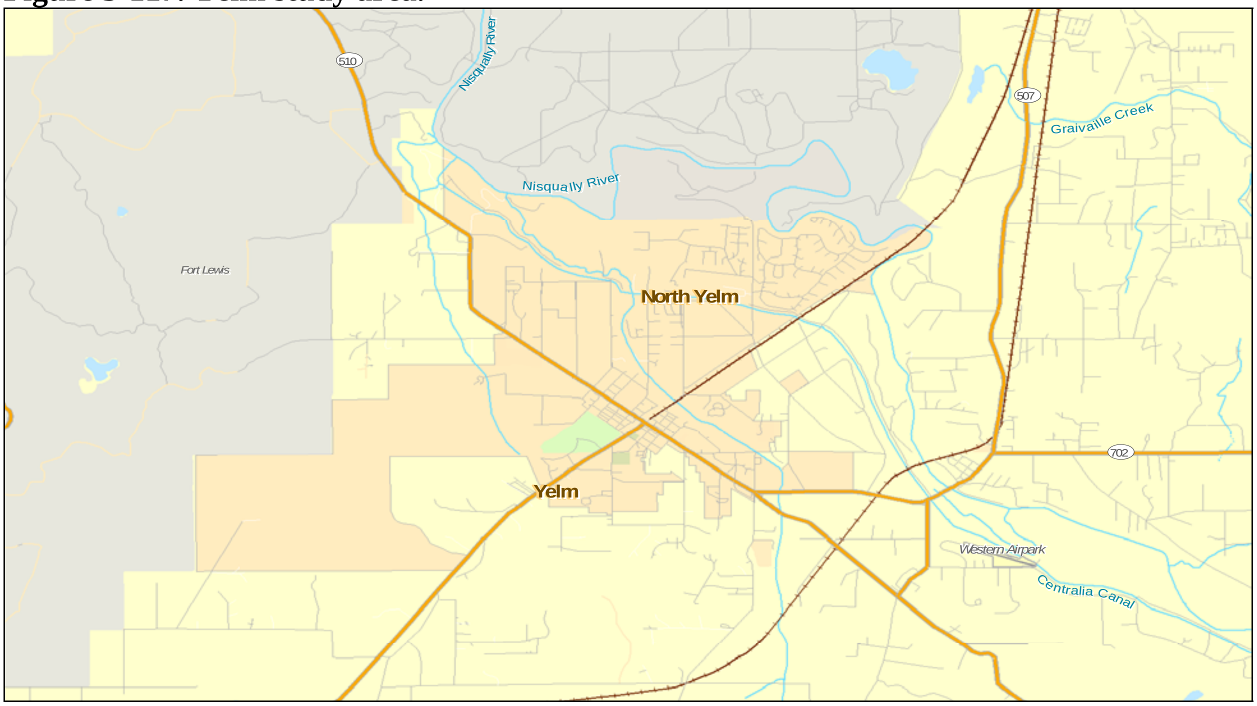


Figure 5-118. Analysis grid and locations of commercial sources. Source locations are indicated by circled X's.

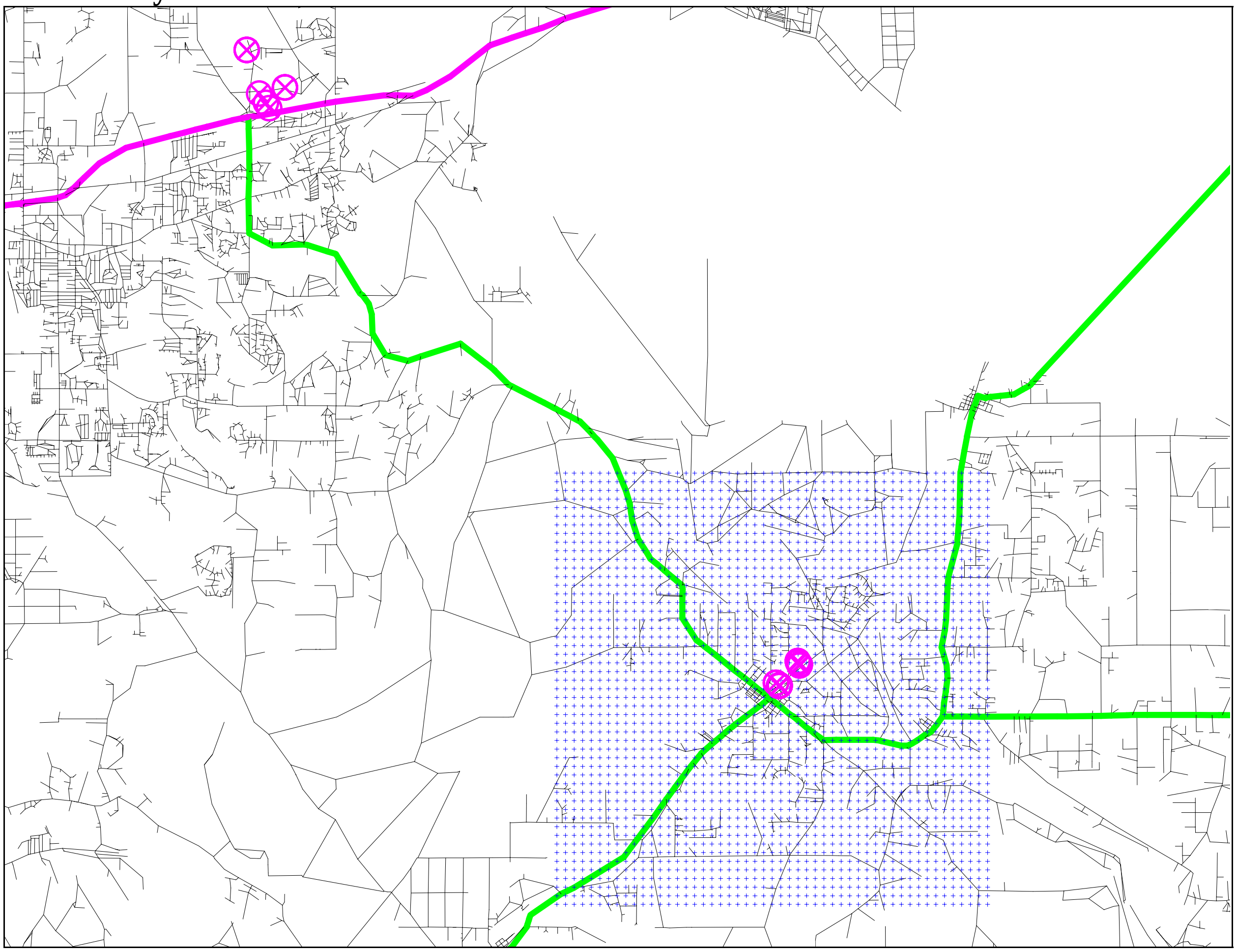


Figure 5-119. Locations of non-commercial sources.
Small magenta squares are locations of on-road freeway, artery, collector and local road sources. (Note that in Yelm there are no freeways or arteries) Green squares are the boundaries of local road area sources. Blue squares are locations of wood stove sources.

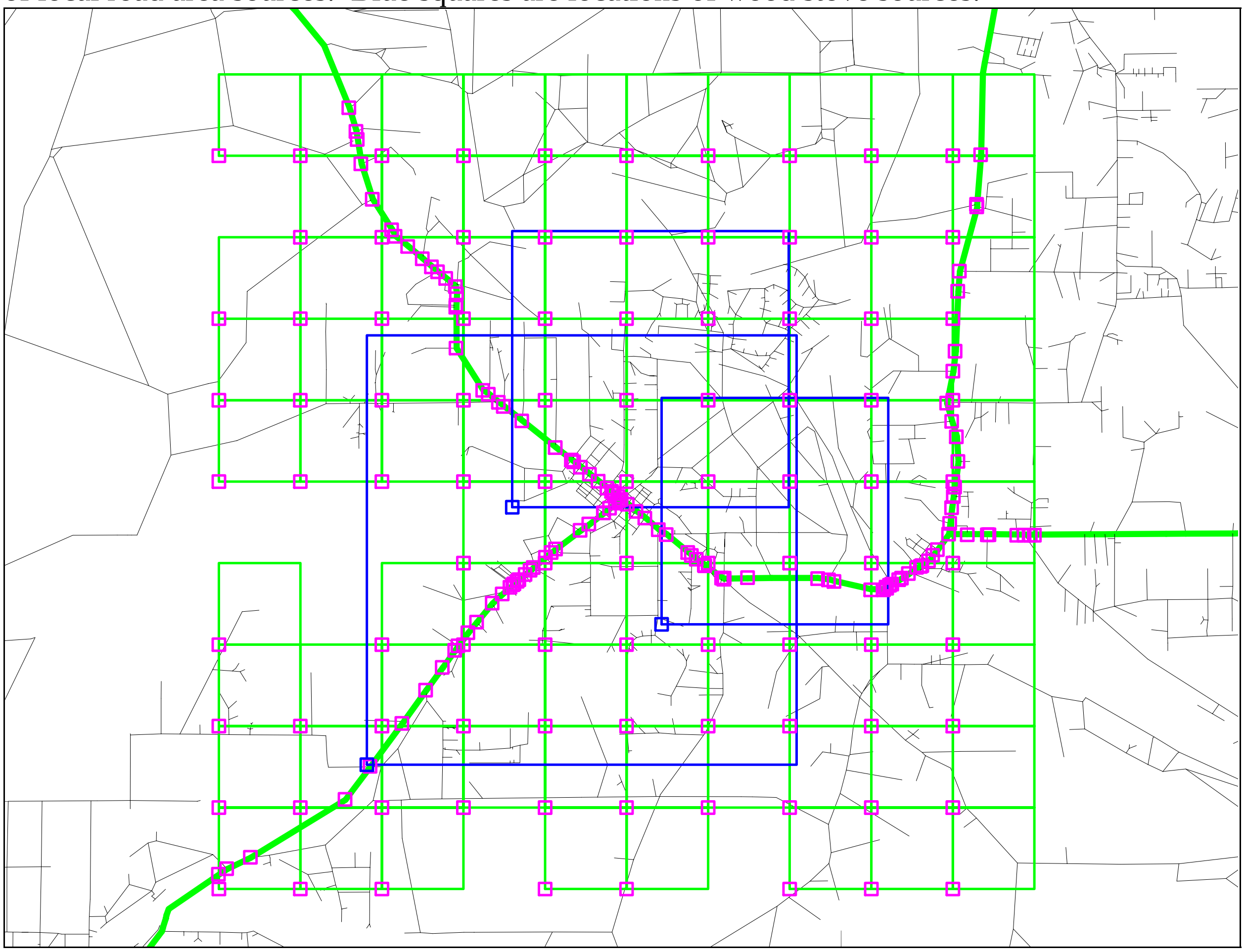
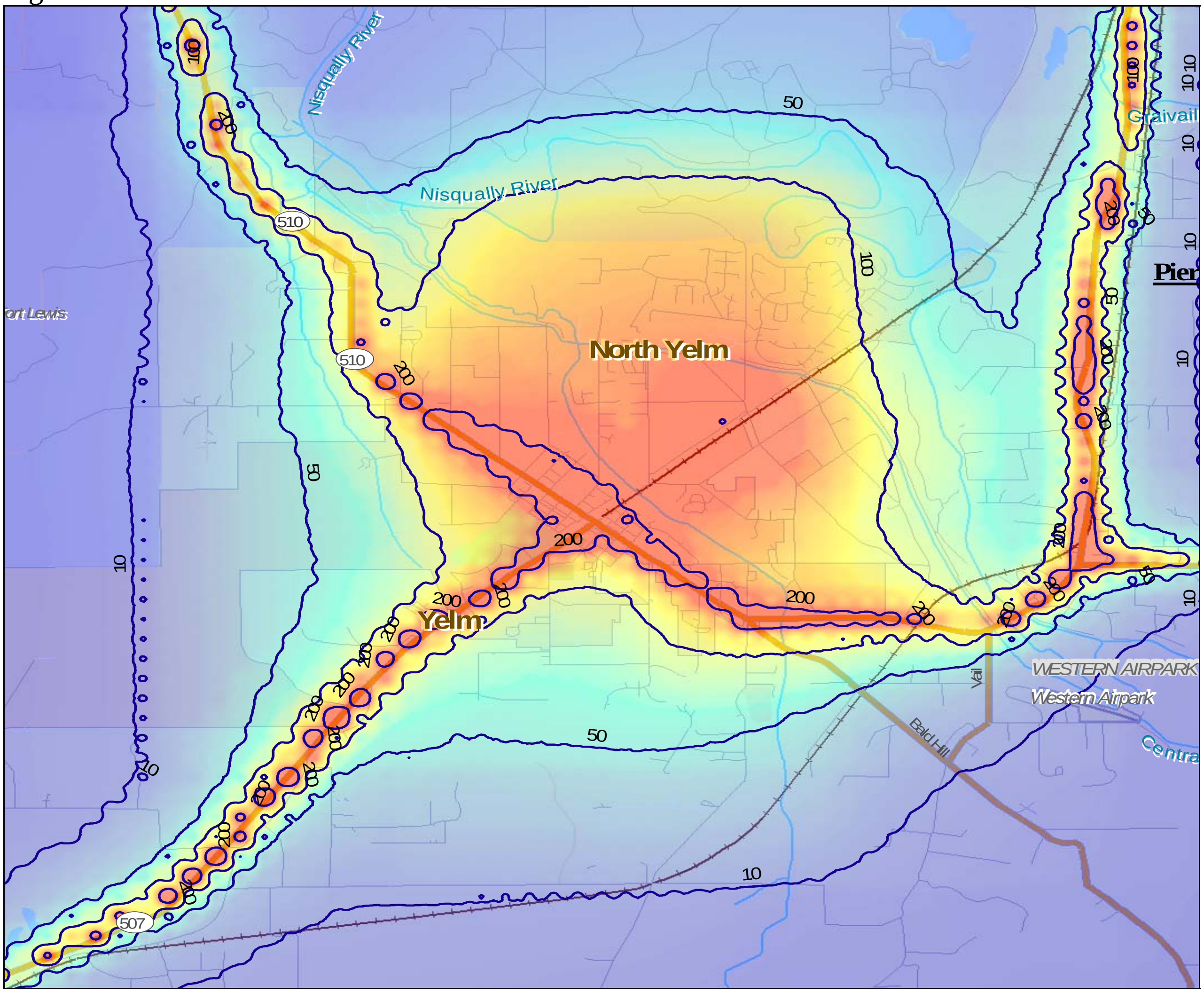


Figure 5-120. Contours of total cancer risk from all sources..



5.4.9.2 Cancer

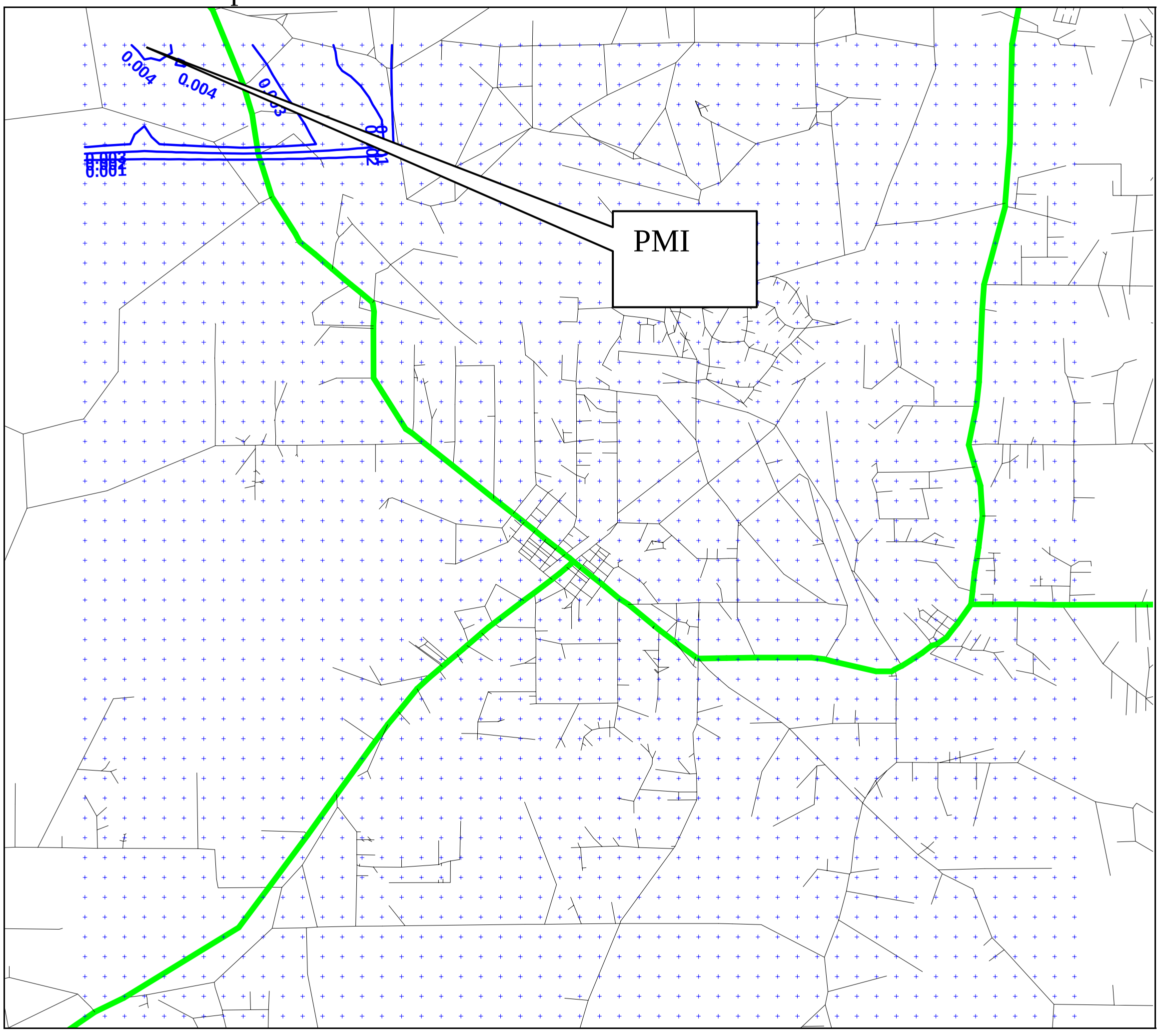
5.4.9.2.1 Point Source (Commercial)

Figure 5-121. Commercial sources included in this study.

Facility	*Stack*	*UTME*	*UTMN*
		meters	*meters*
NUTRIOM LLC	stack 2471	517801	5213813
THURSTON COUNTY WASTE AND RECOVERY CENTER - Landfill	stack 1002	518092	5212800
AMTECH CORPORATION	stack 16711	530158	5199062
AMTECH CORPORATION	stack 16712	530172	5199081
AMTECH CORPORATION	stack 16713	530177	5199069
AMTECH CORPORATION	stack 1672	530092	5199133
THURSTON COUNTY WASTE AND RECOVERY CENTER - Landfill	stack 1001	518247	5212584
RT LONDON - NORSE	stack 2432	518689	5212941
LAKESIDE INDUSTRIES - LACEY	stack 621	518322	5212462
NUTRIOM LLC	stack 2472	517801	5213813
LASCO BATHWARE	stack 52	530596	5199638
LASCO BATHWARE	stack 53	530642	5199561
LASCO BATHWARE	stack 55	530637	5199541
LASCO BATHWARE	stack 56	530602	5199612
RT LONDON - NORSE	stack 2431	518689	5212941

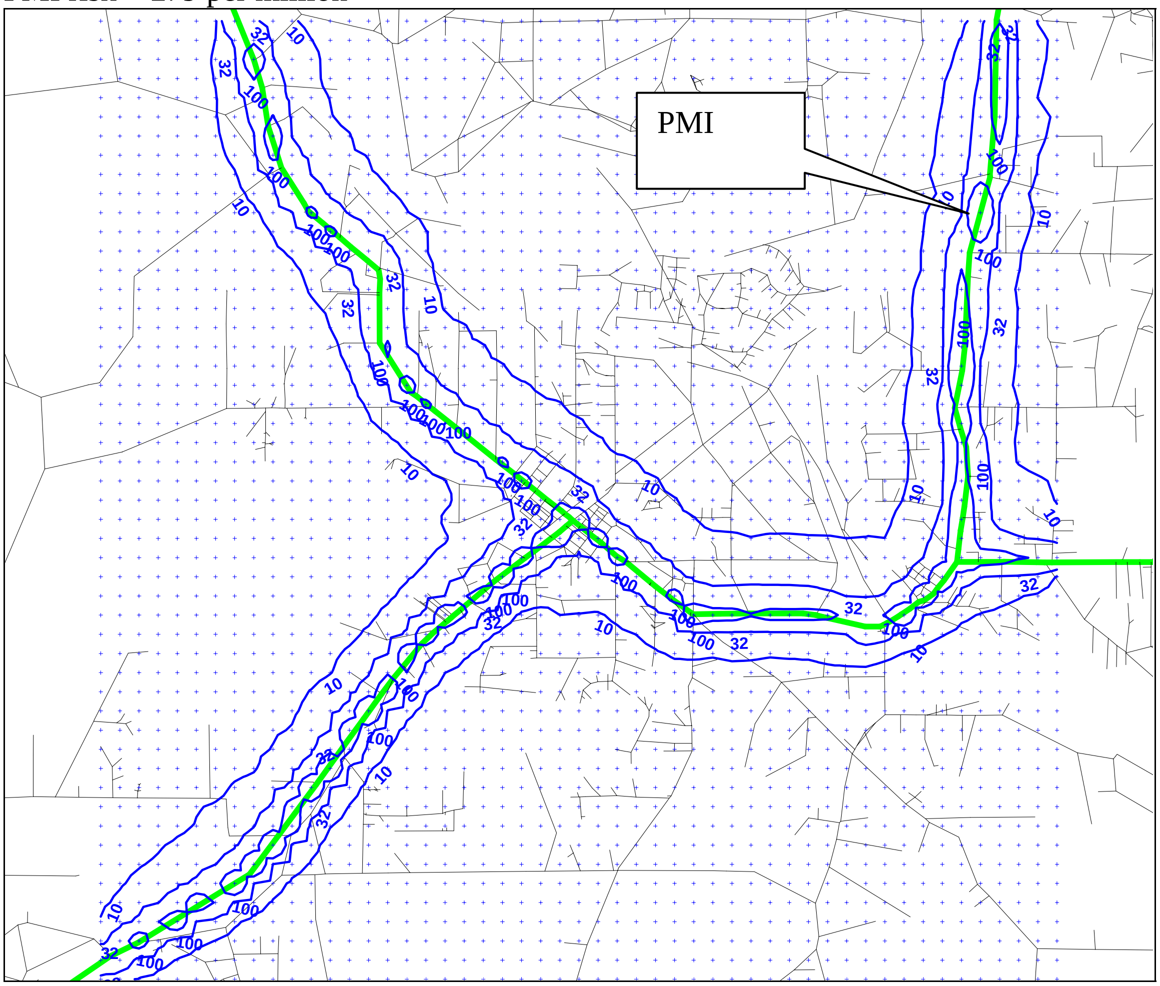
Figure 5-122. Yelm, commercial, cancer.

PMI risk = 0.004 per million



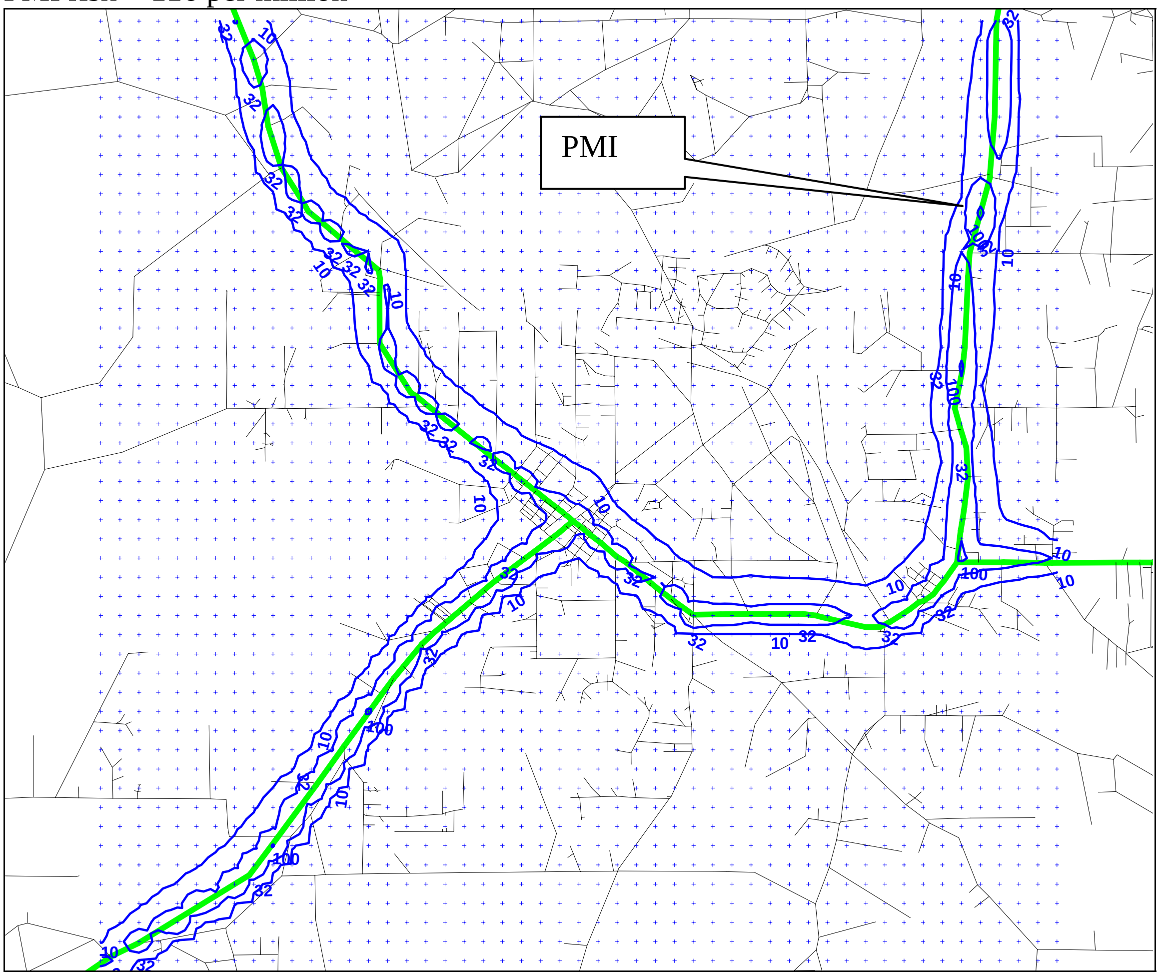
5.4.9.2.2 Diesel On-road

Figure 5-123. Yelm, on-road diesel, cancer.
PMI risk = 279 per million



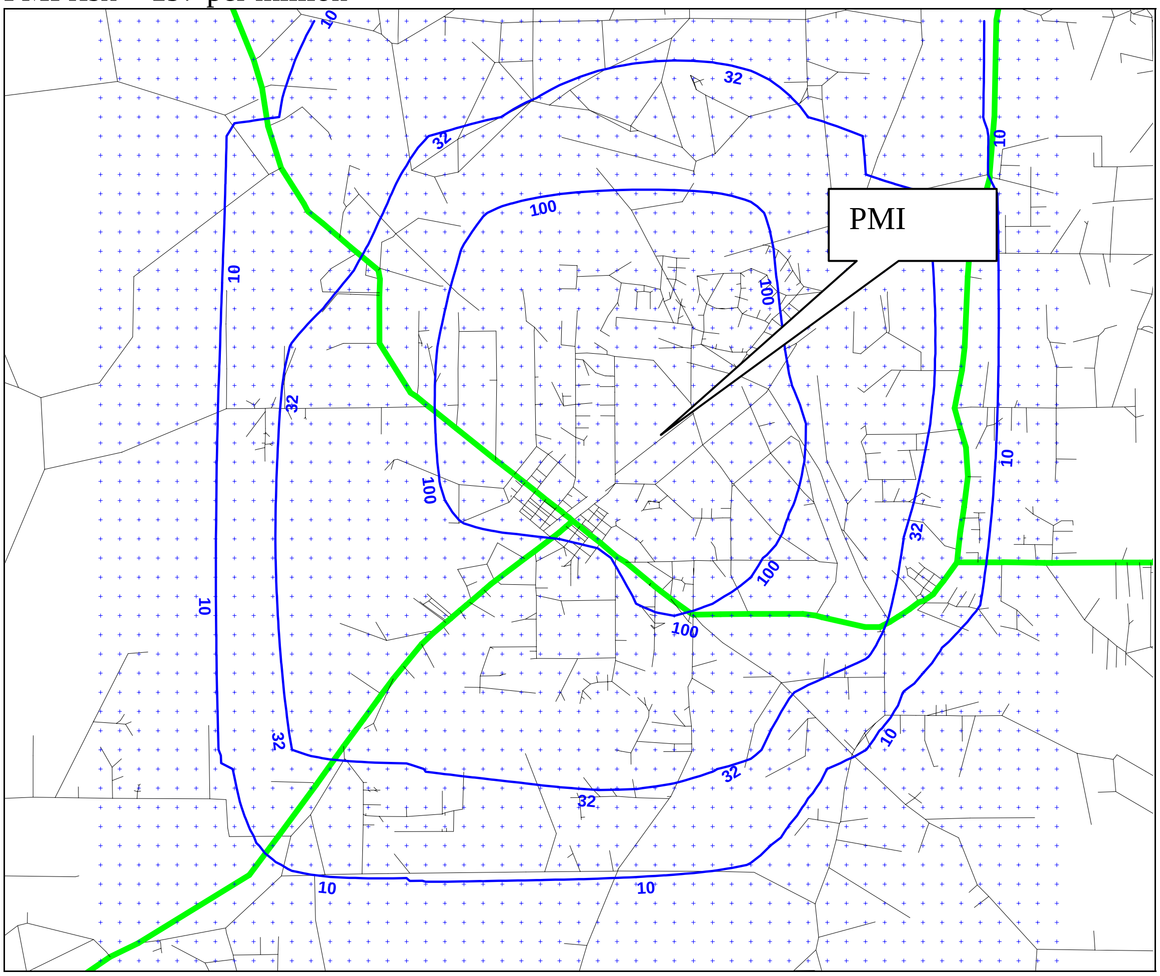
5.4.9.2.3 Gasoline On-road

Figure 5-124. Yelm, on-road gasoline, cancer.
PMI risk = 116 per million



5.4.9.2.4 Wood Stoves and Fireplaces

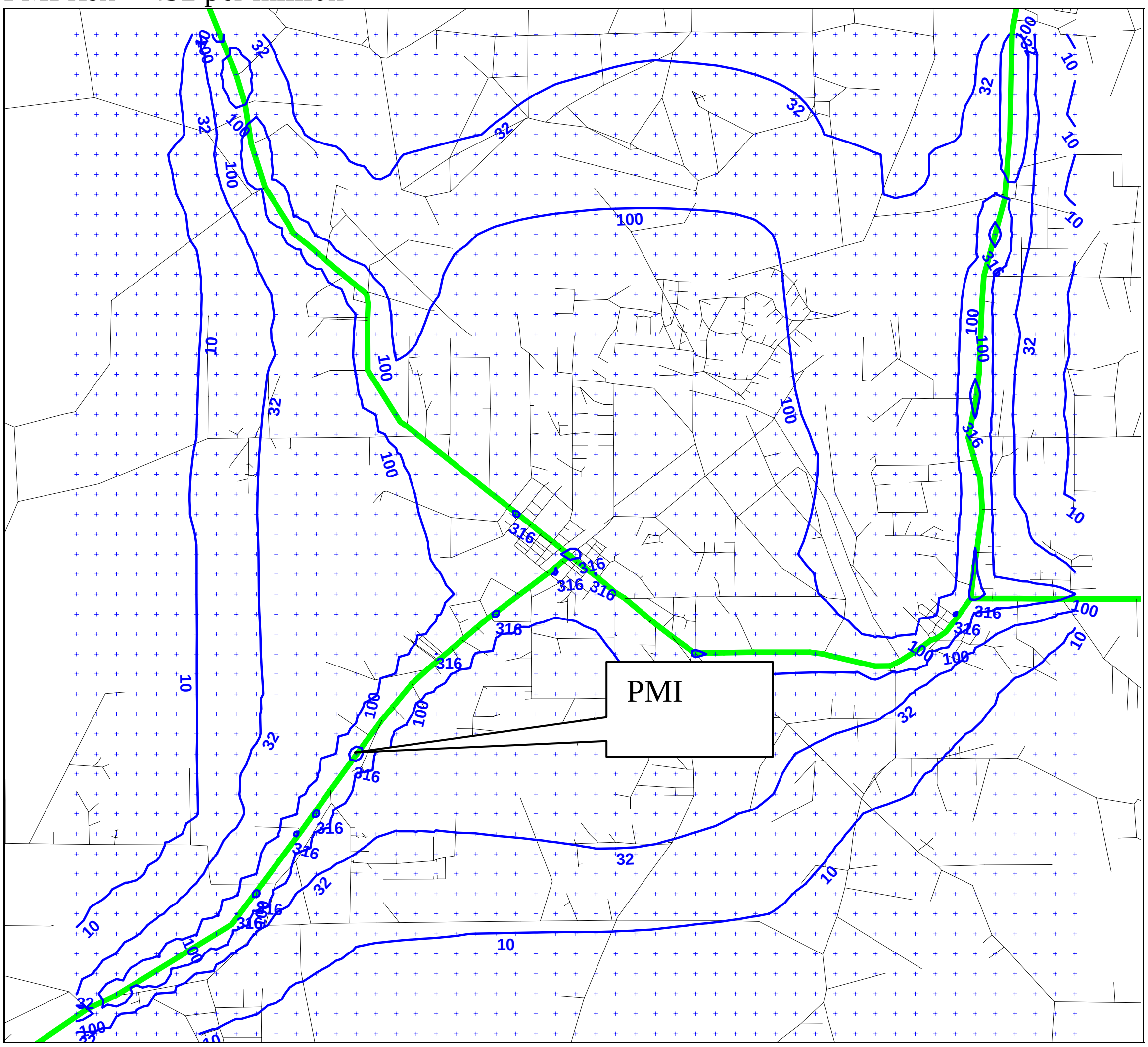
Figure 5-125. Yelm, wood stoves, cancer.
PMI risk = 197 per million



5.4.9.2.5 Total Cancer Risk

Figure 5-126. Yelm, all sources, cancer.

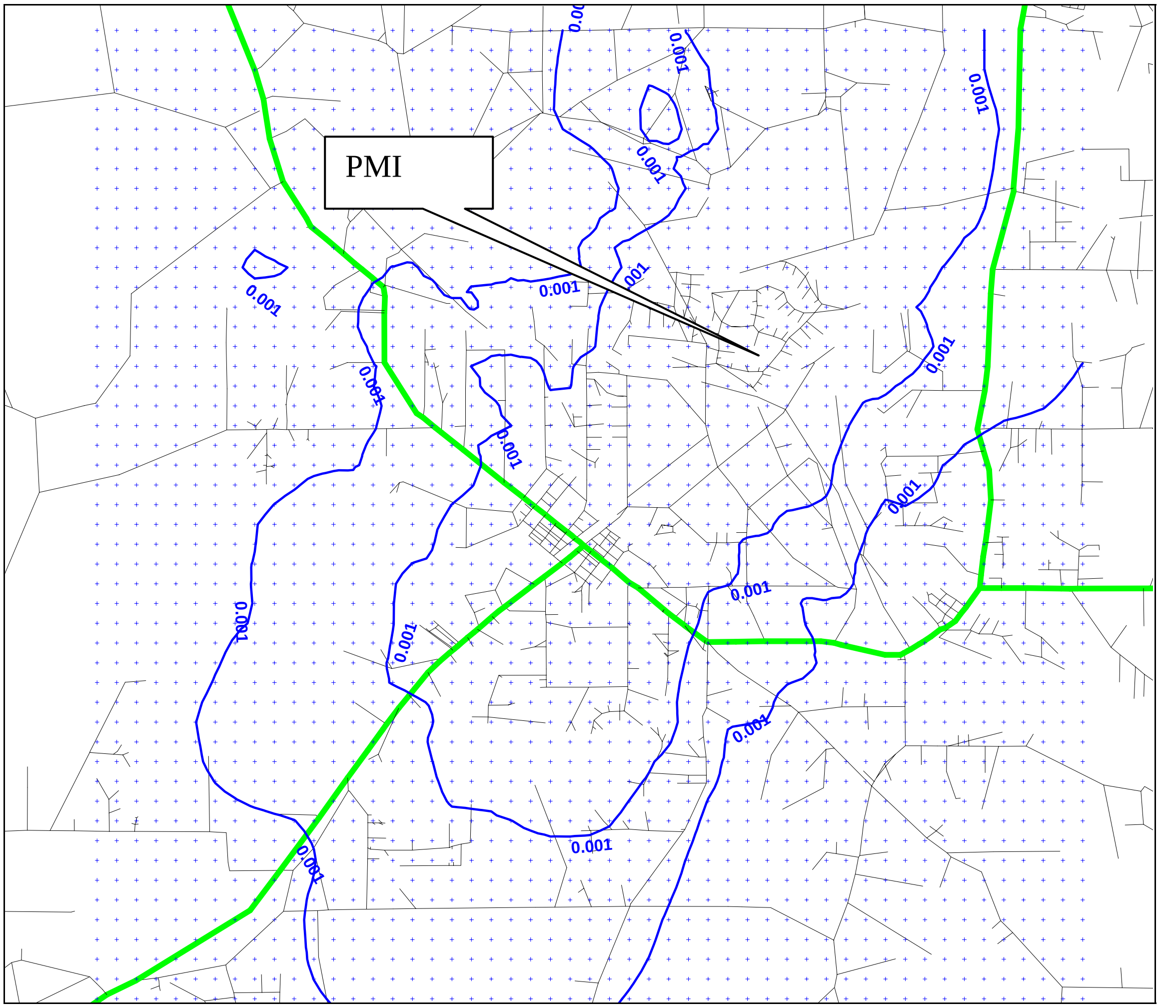
PMI risk = 432 per million



5.4.9.3 Chronic Non-cancer

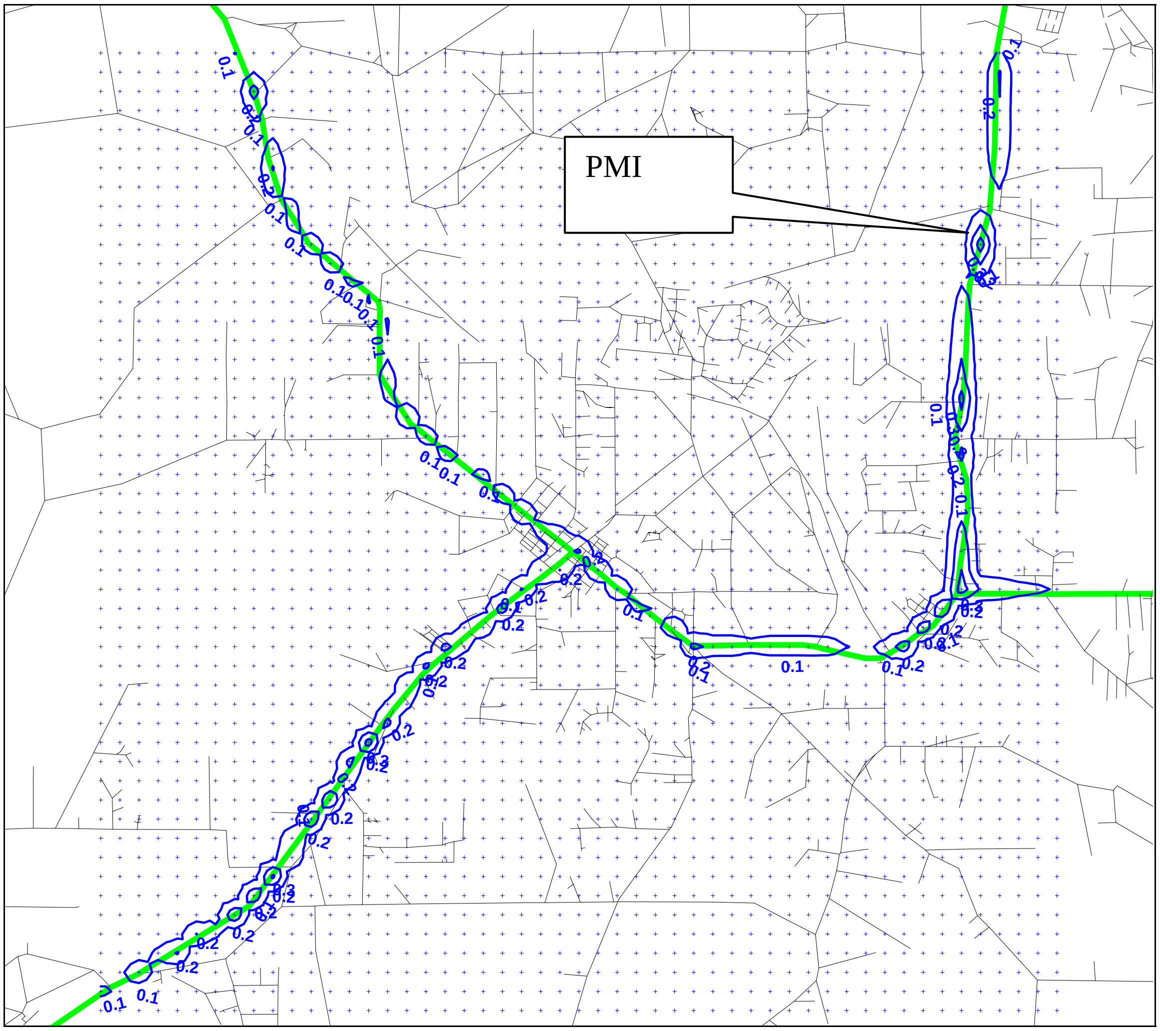
5.4.9.3.1 Point Source (Commerical)

Figure 5-127. Yelm, commercial, chronic non-cancer HHI.
PMI risk = 0.001



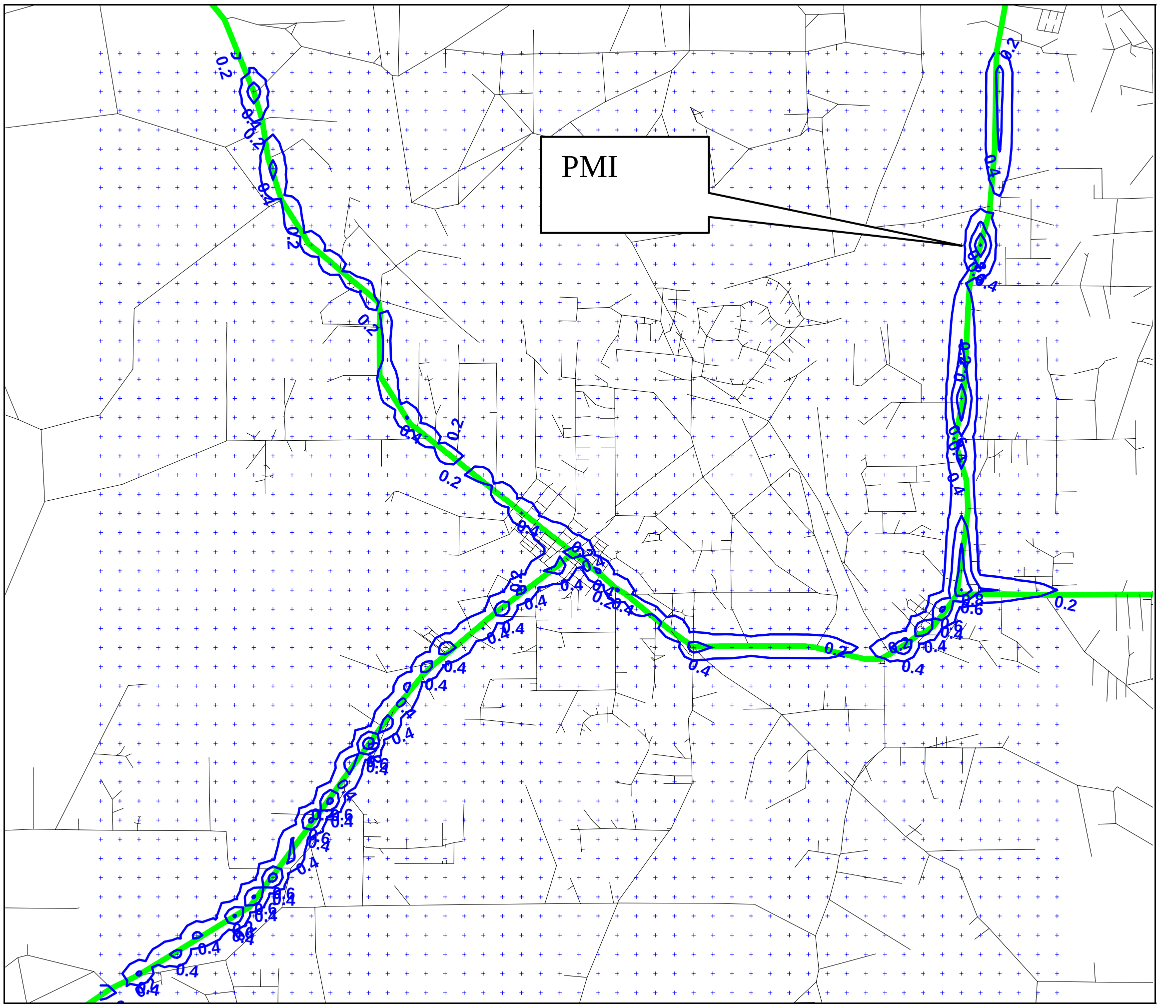
5.4.9.3.2 Diesel On-road

Figure 5-128. Yelm, on-road diesel, chronic non-cancer HHI.
PMI risk = 0.35



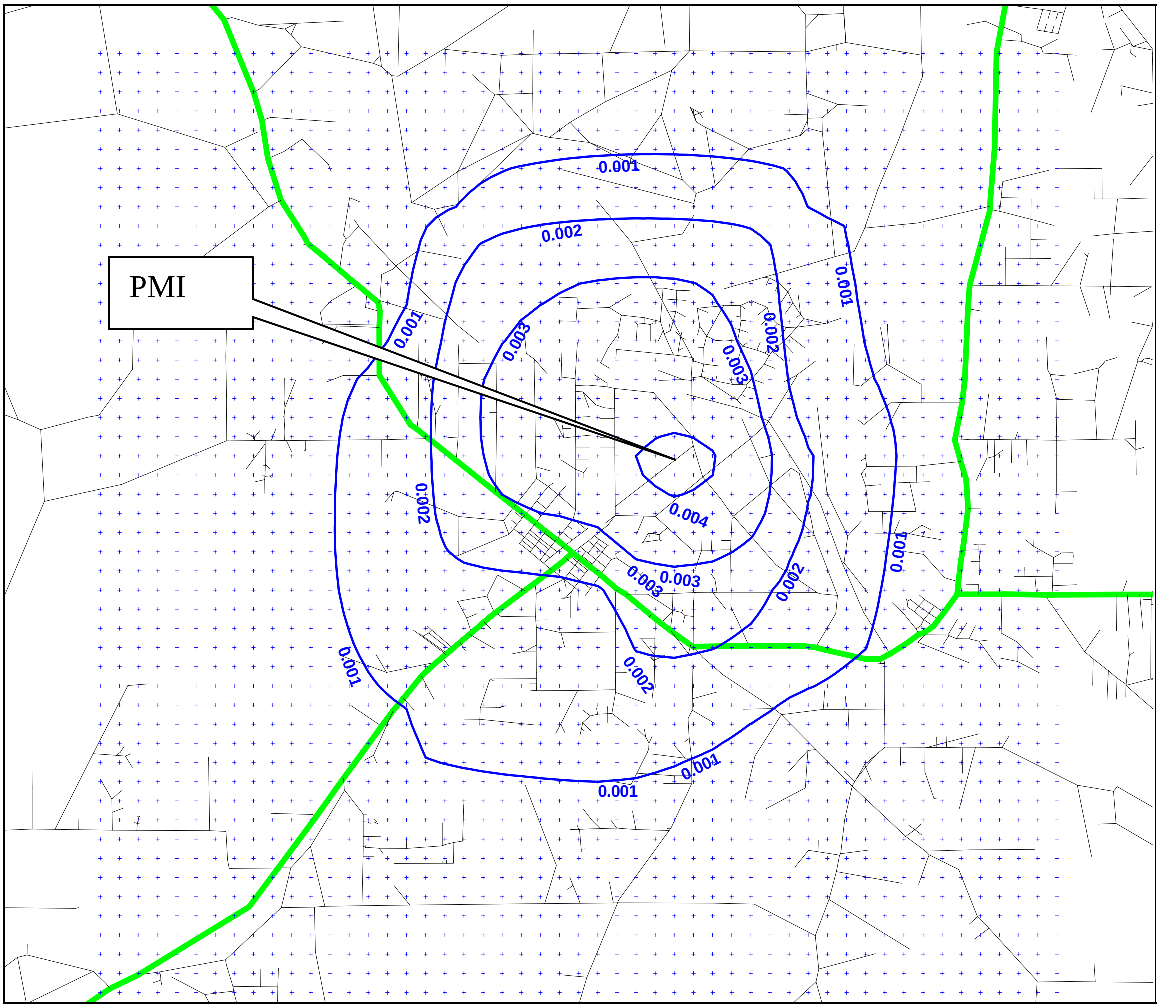
5.4.9.3.3 Gasoline On-road

Figure 5-129. Yelm, on-road gasoline, chronic non-cancer HHI.
PMI risk = 0.81



5.4.9.3.4 Wood Stoves and Fireplaces

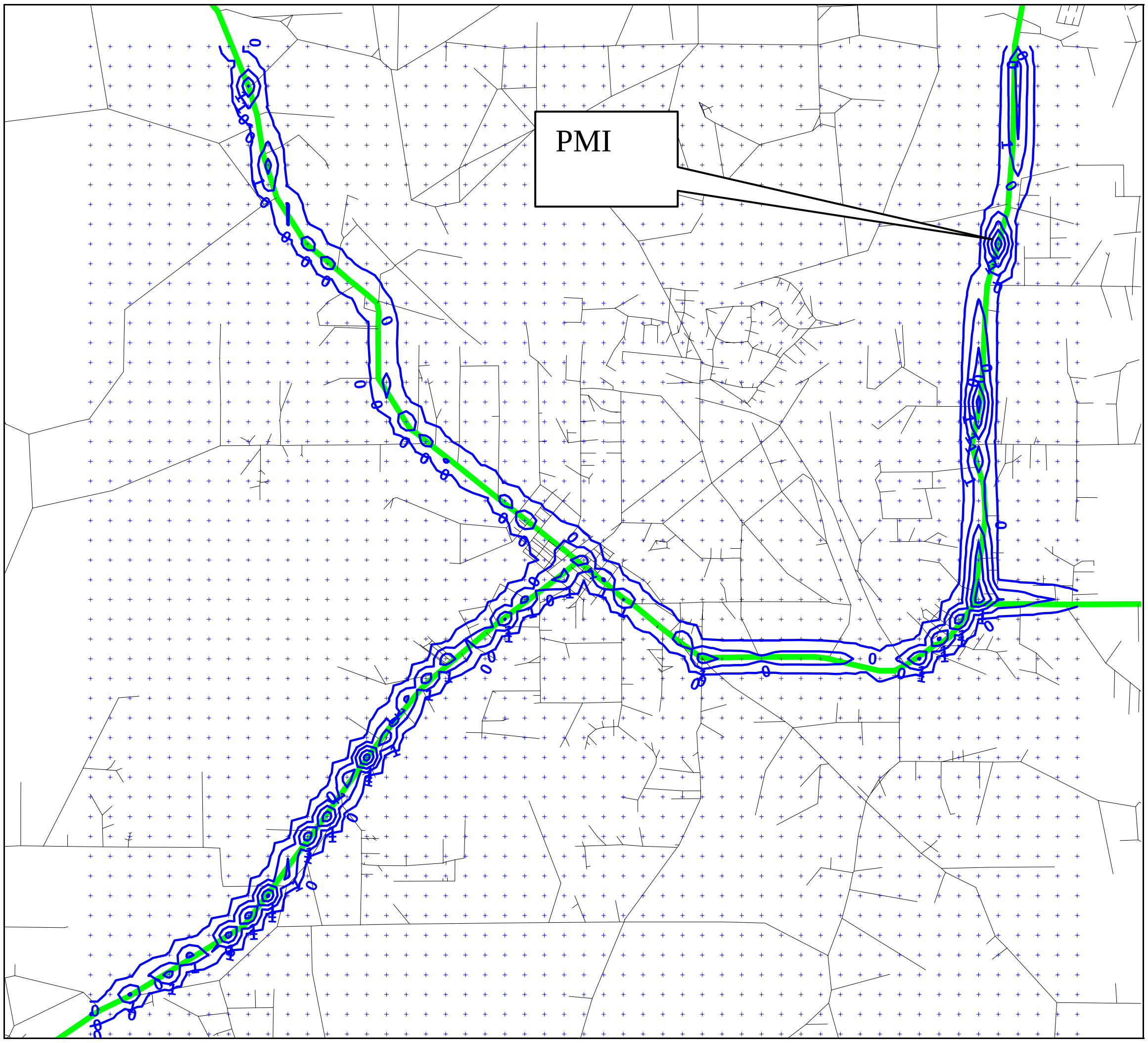
Figure 5-130. Yelm, wood stoves, chronic non-cancer HHI.
PMI risk = 0.0041



5.4.9.3.5 Total Chronic Risk

Figure 5-131. Yelm, all sources, chronic non-cancer HHI.

PMI risk = 1.17



5.4.10 Shelton

5.4.10.1 Summary

Figure 5-132. Shelton study area.

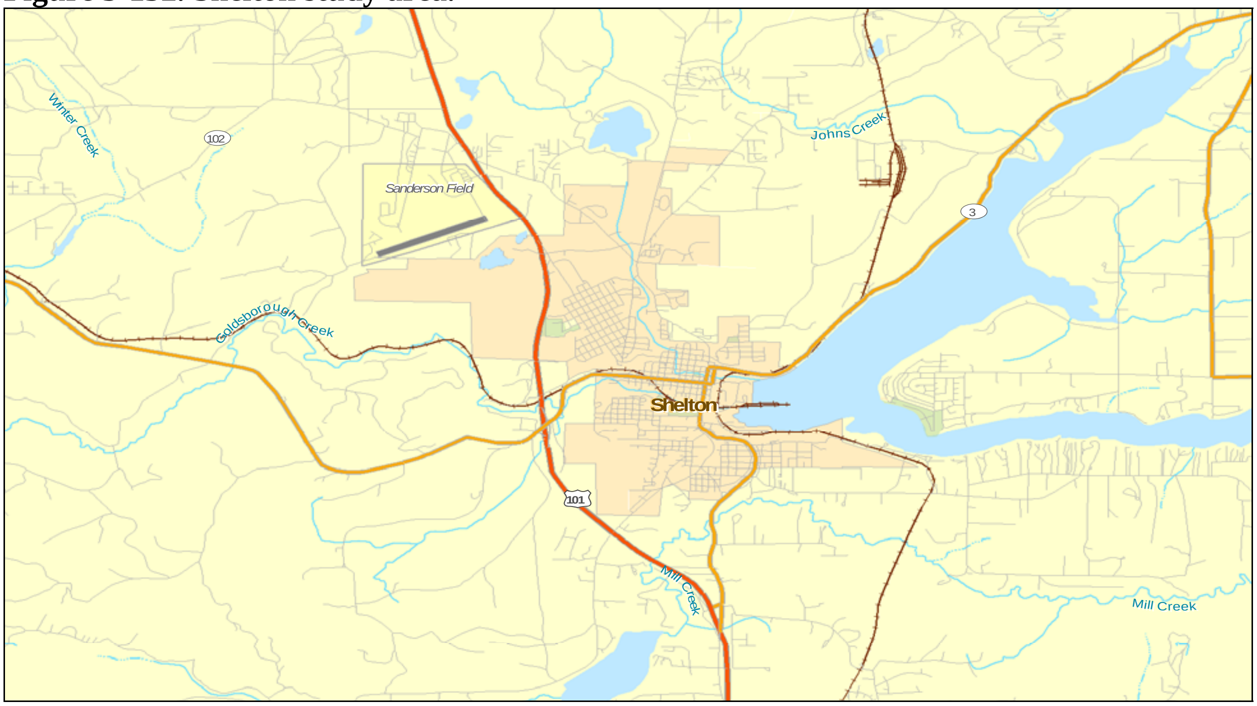


Figure 5-133. Analysis grid and locations of commercial sources. Source locations are indicated by circled X's.

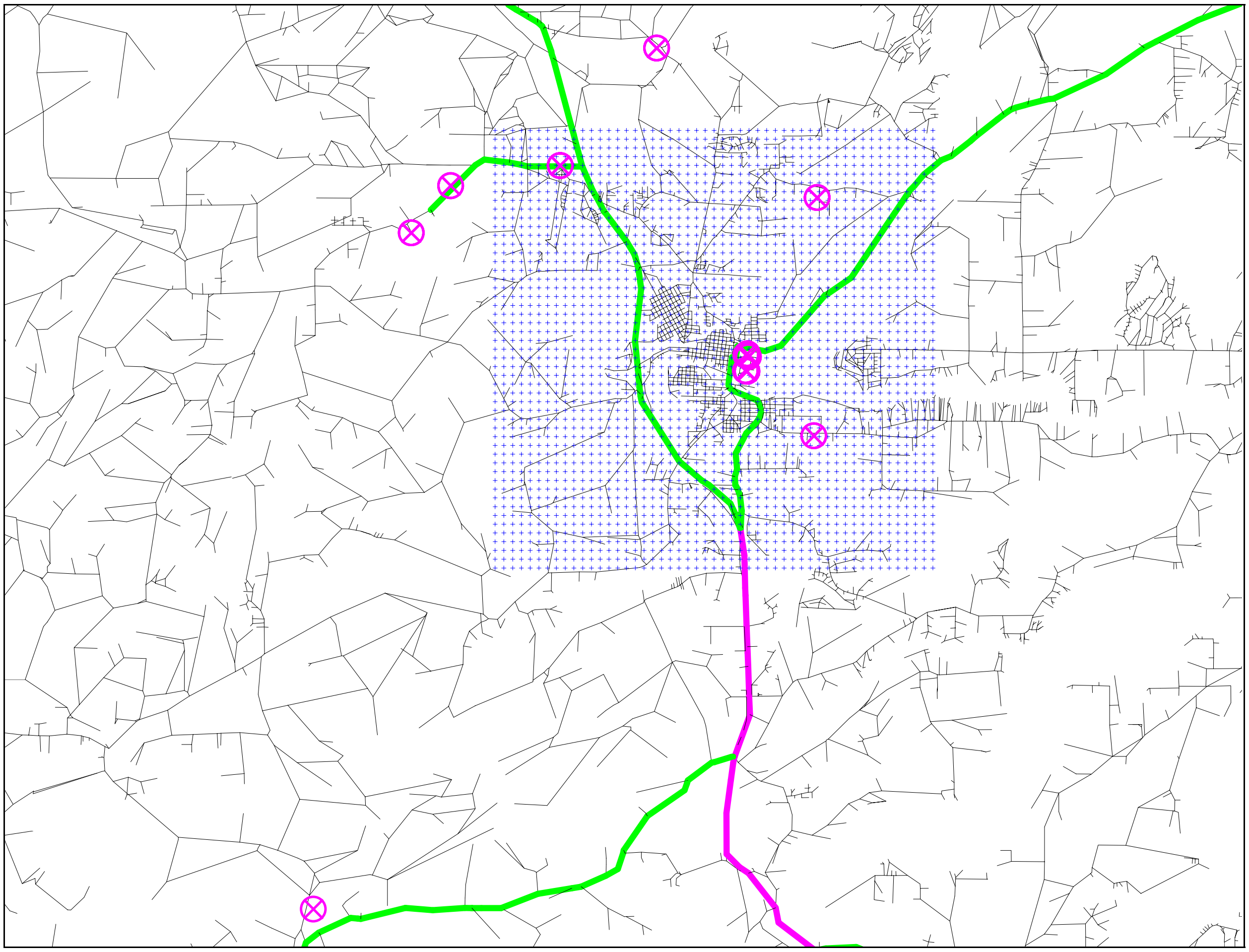


Figure 5-134. Locations of non-commercial sources. .
Small magenta squares are locations of on-road freeway, artery, collector and local road sources. Green squares are the boundaries of local road area sources. Blue squares are locations of wood stove sources.

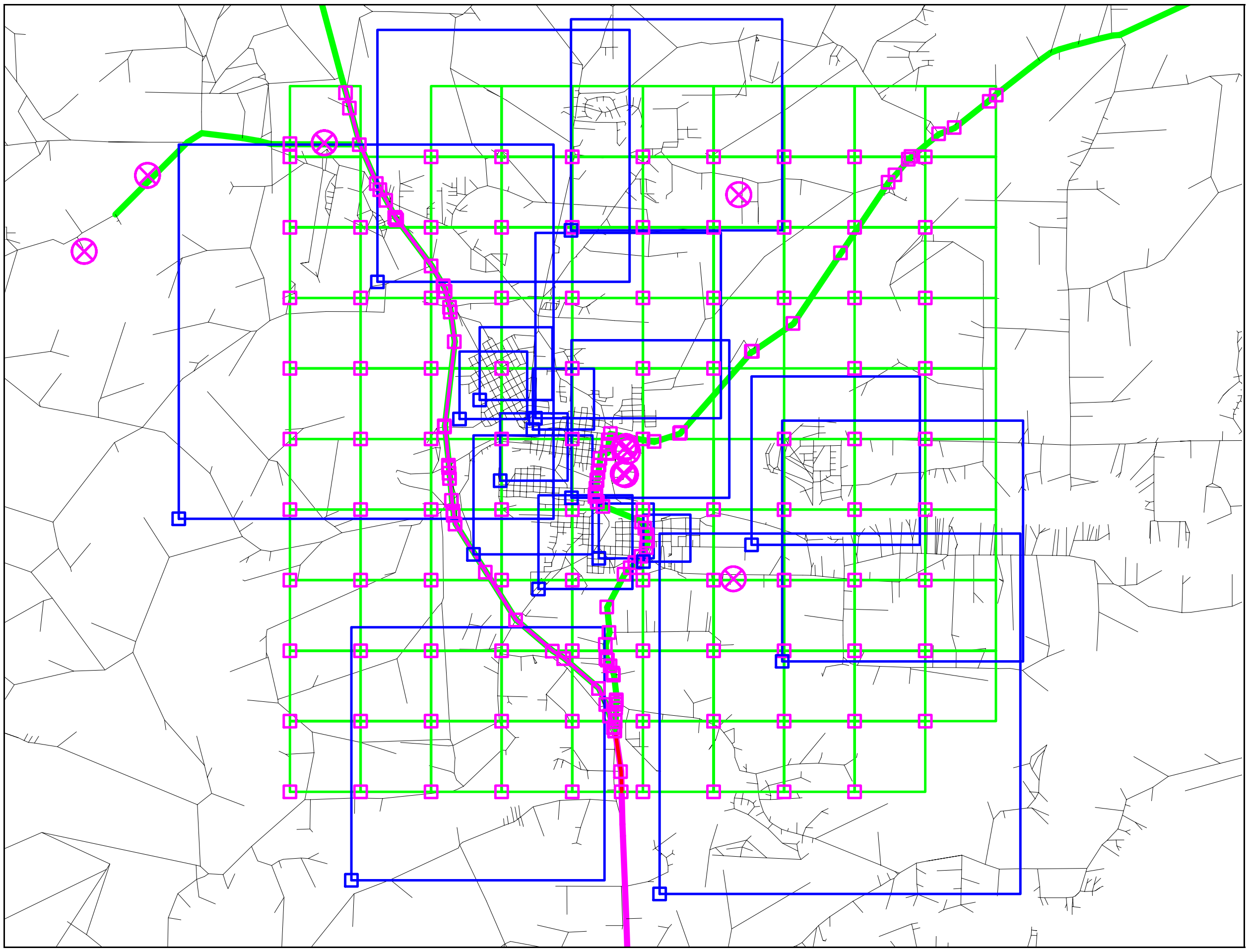
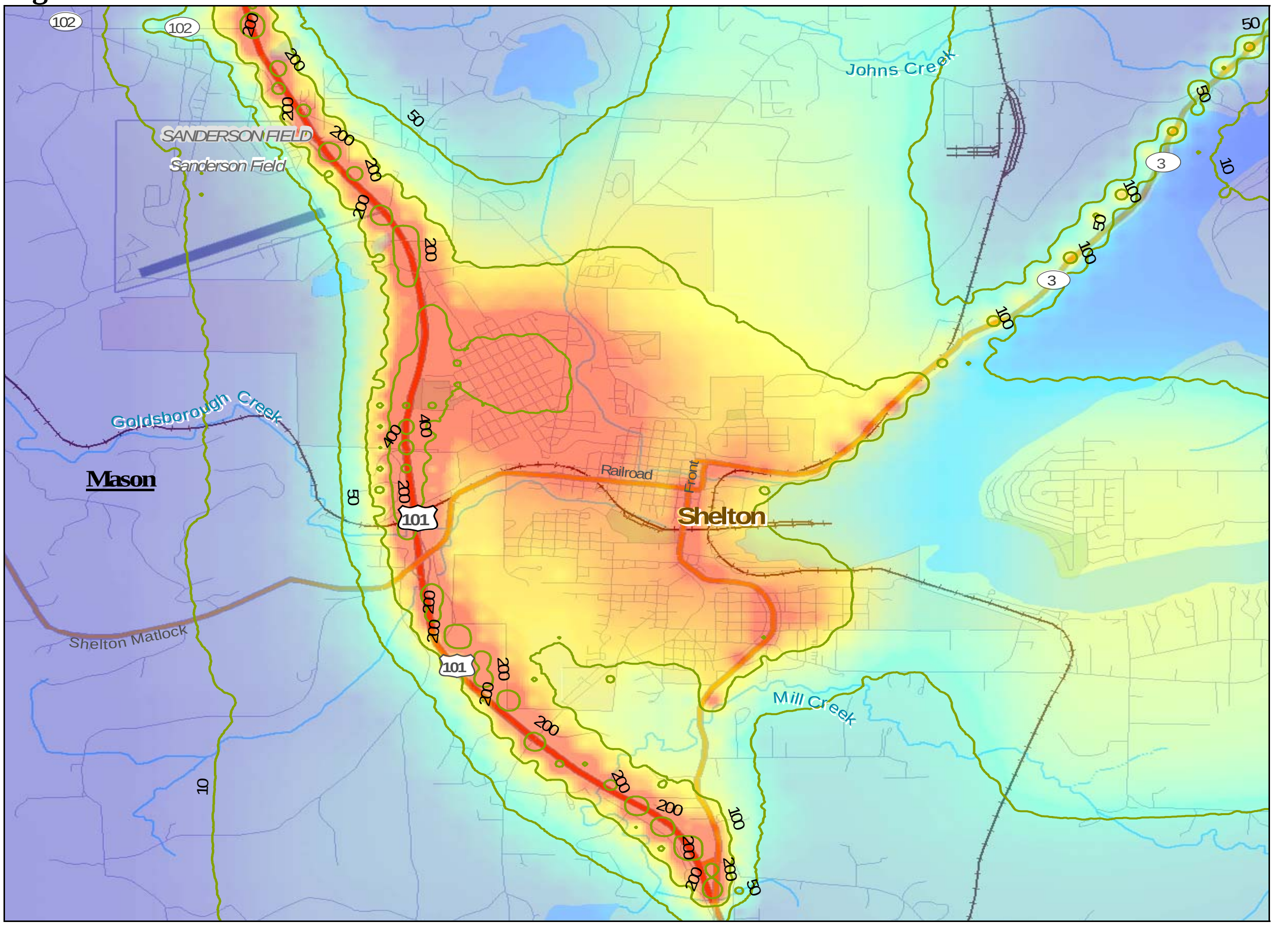


Figure 5-135. Contours of total cancer risk from all sources.



5.4.10.2 Cancer

5.4.10.2.1 Point Source (Commerical)

Figure 5-136. Commercial sources included in this study.

Facility	***Stack***	***UTME***	***UTMN***
		meters	***meters***
MASON COUNTY PUD-OLYMPIC VIEW GENERATING STATION	stack 12081	485986	5232735
OLYMPIC PANEL PRODUCTS LLC	stack 6711	492723	5228508
MASON COUNTY FOREST PRODUCTS	stack 1087	494359	5232462
OLYMPIC PANEL PRODUCTS LLC	stack 6710	492762	5228892
OLYMPIC PANEL PRODUCTS LLC	stack 6715	492731	5228865
WELCO-SKOOKUM LUMBER	stack 1041	482849	5216201
ACE PAVING -SHELTON	stack 1851	490691	5235882
AERO CONTROLS INC	stack 2261	488488	5233196
AERO CONTROLS INC	stack 2262	488488	5233196
CRAGER PREHUNG DOOR	stack 331	494283	5227018
SIMPSON TIMBER CO	stack 678	492754	5228492
WASHINGTON CORRECTIONS CENTER	stack 691	485087	5231658
OLYMPIC PANEL PRODUCTS LLC	stack 675	492785	5228823

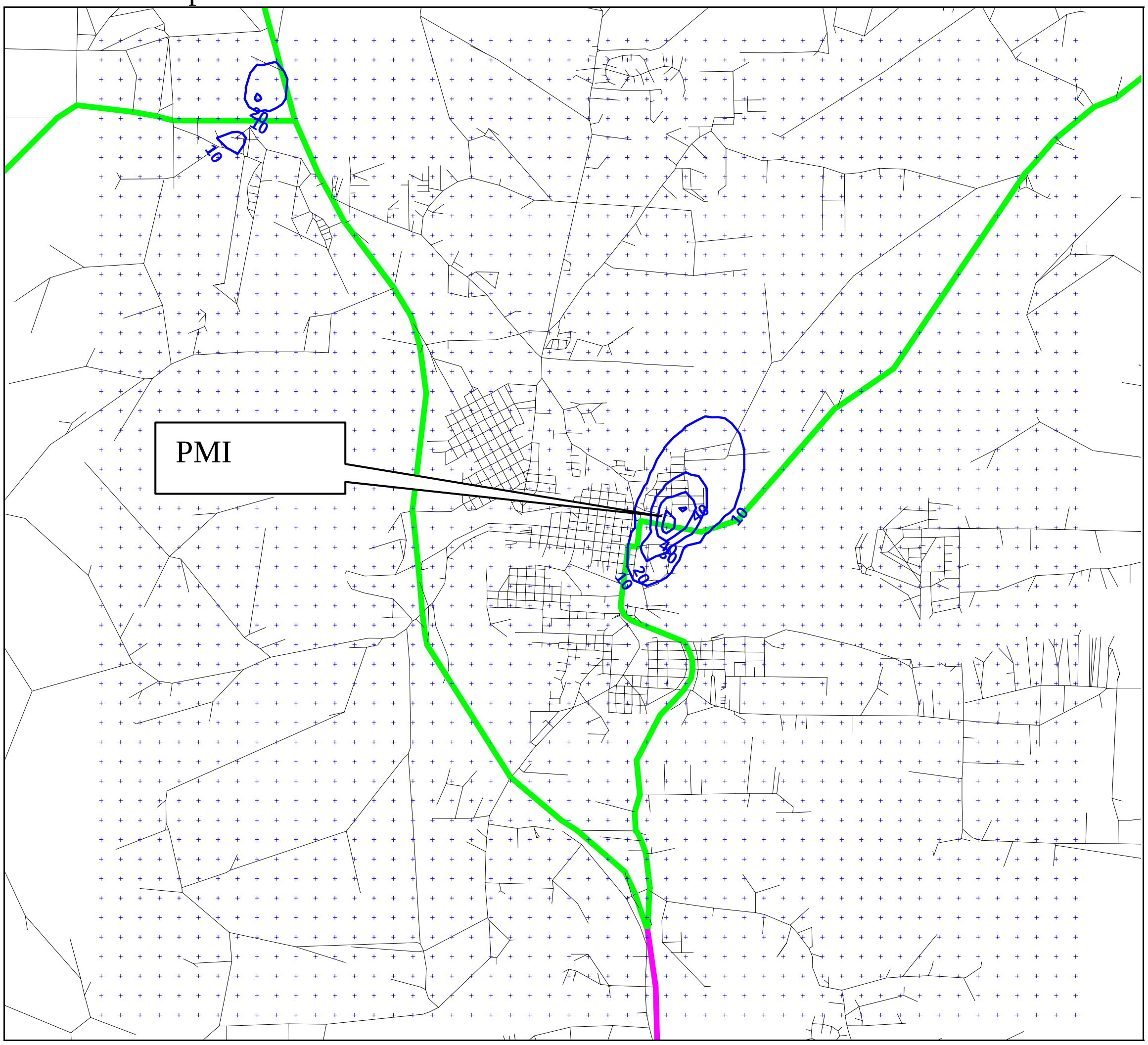
Table 5-32. Pollutants contributing to cancer risk.

CAS	POLLUTANT NAME	INHAL	DERM	SOIL	TOTAL
50000	Formaldehyde	4.53E-05	0.00E+00	0.00E+00	4.53E-05

Table 5-33. Emission of pollutants contributing to cancer risk.
Formaldehyde

Facility	Annual EMS (lbs/yr)
OLYMPIC PANEL PRODUCTS LLC	24594
SIMPSON TIMBER CO	2629
ACE PAVING -SHELTON	24

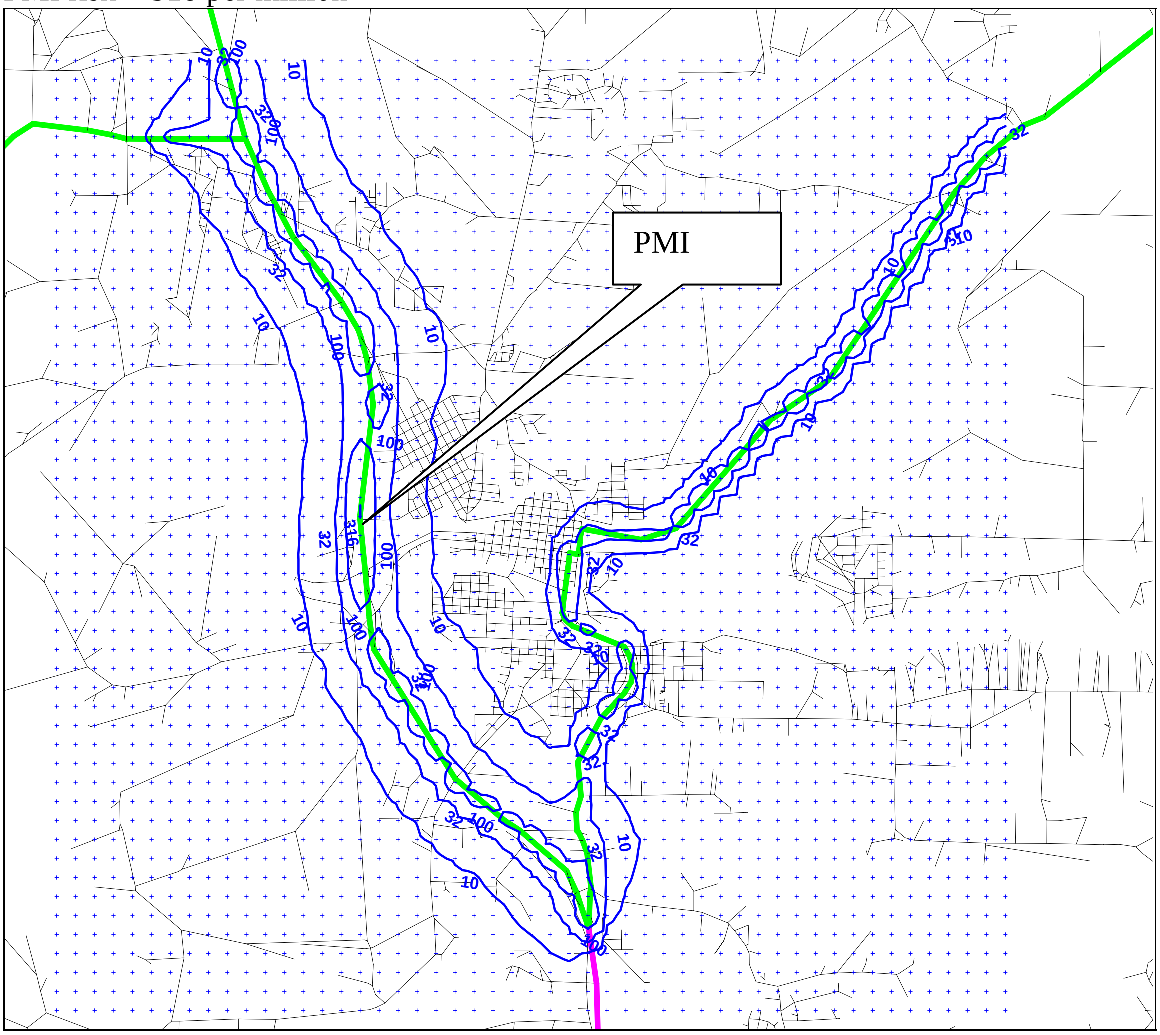
Figure 5-137. Shelton, commercial, cancer.
PMI risk = 46 per million



5.4.10.2.2 Diesel On-road

Figure 5-138. Shelton, on-road diesel, cancer.

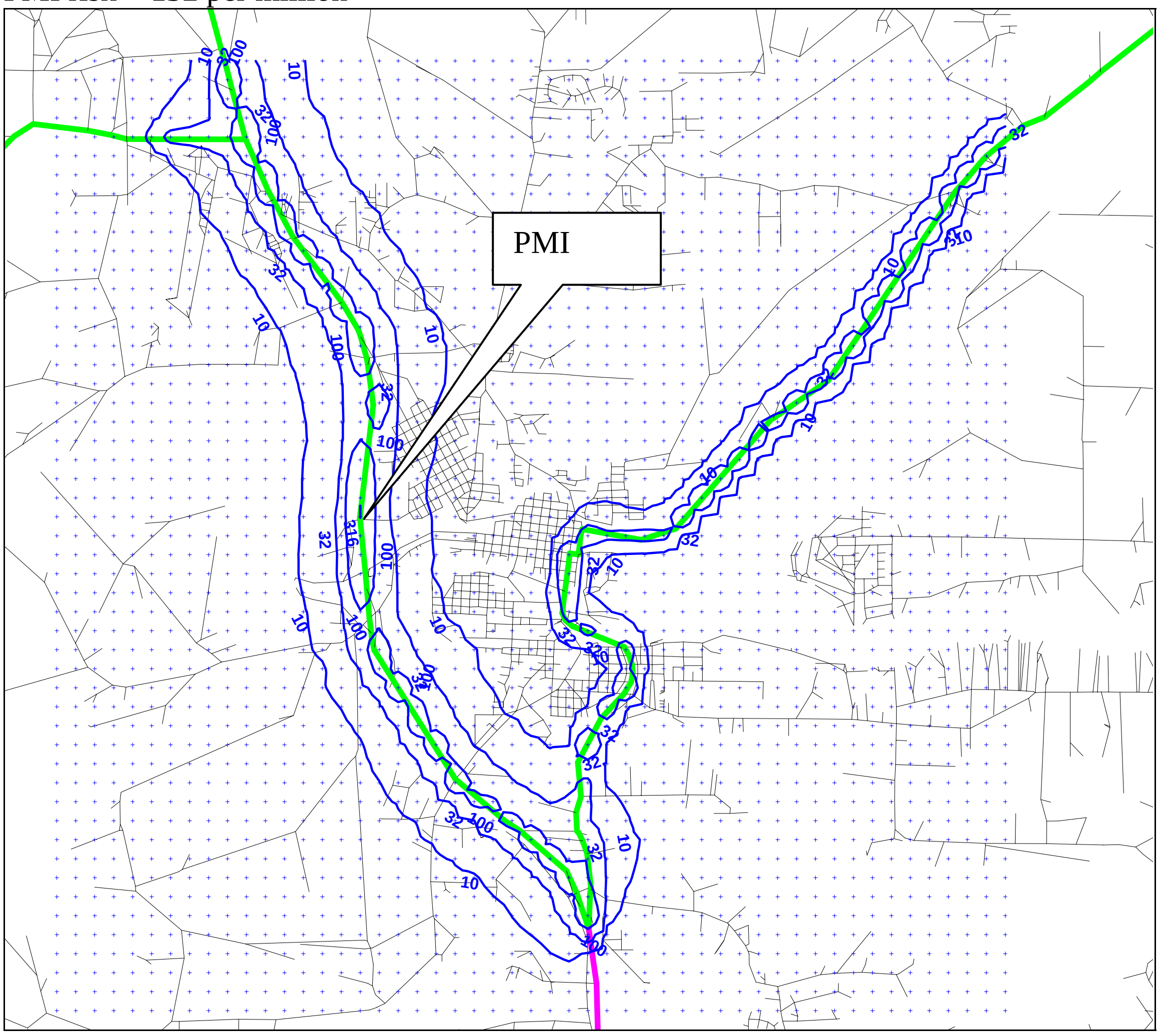
PMI risk = 318 per million



5.4.10.2.3 Gasoline On-road

Figure 5-139. Shelton, on-road gasoline, cancer.

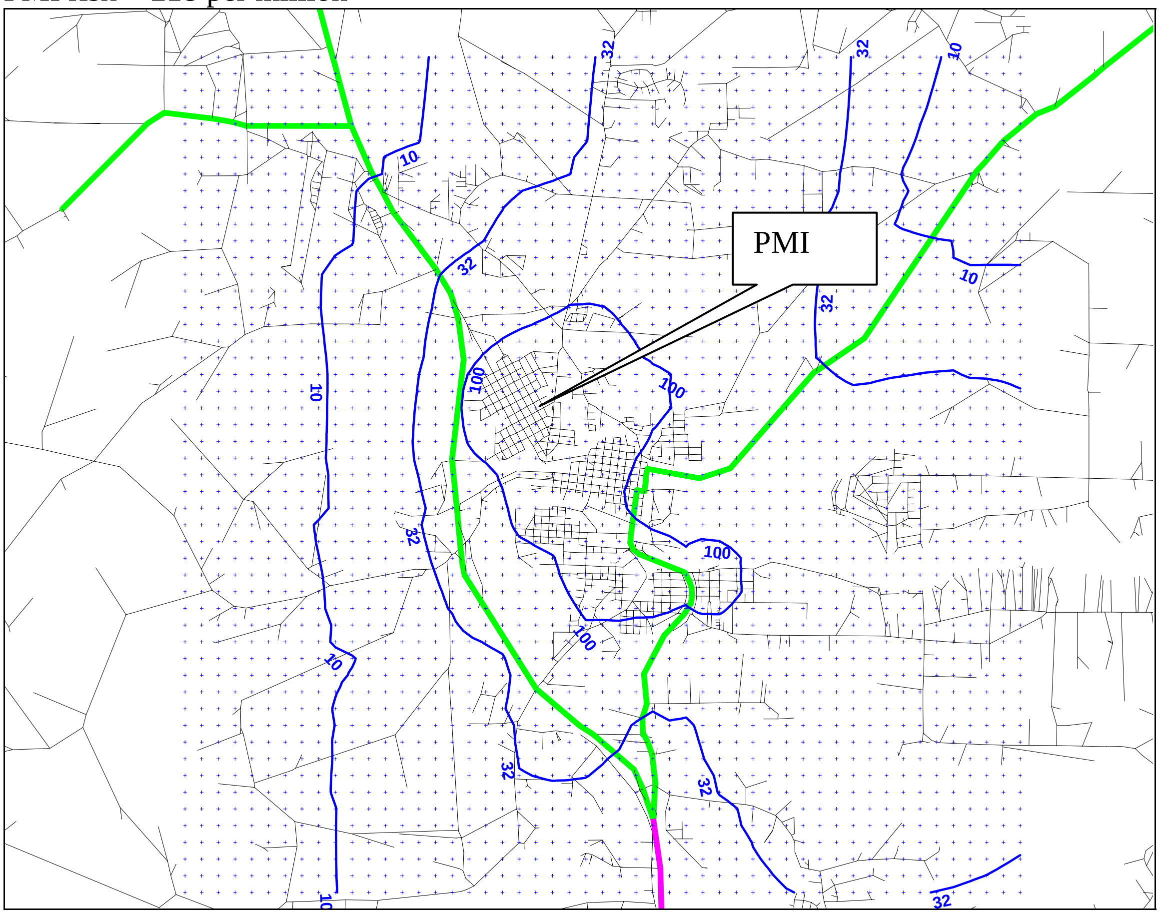
PMI risk = 132 per million



5.4.10.2.4 Wood Stoves and Fireplaces

Figure 5-140. Shelton, wood stoves, cancer.

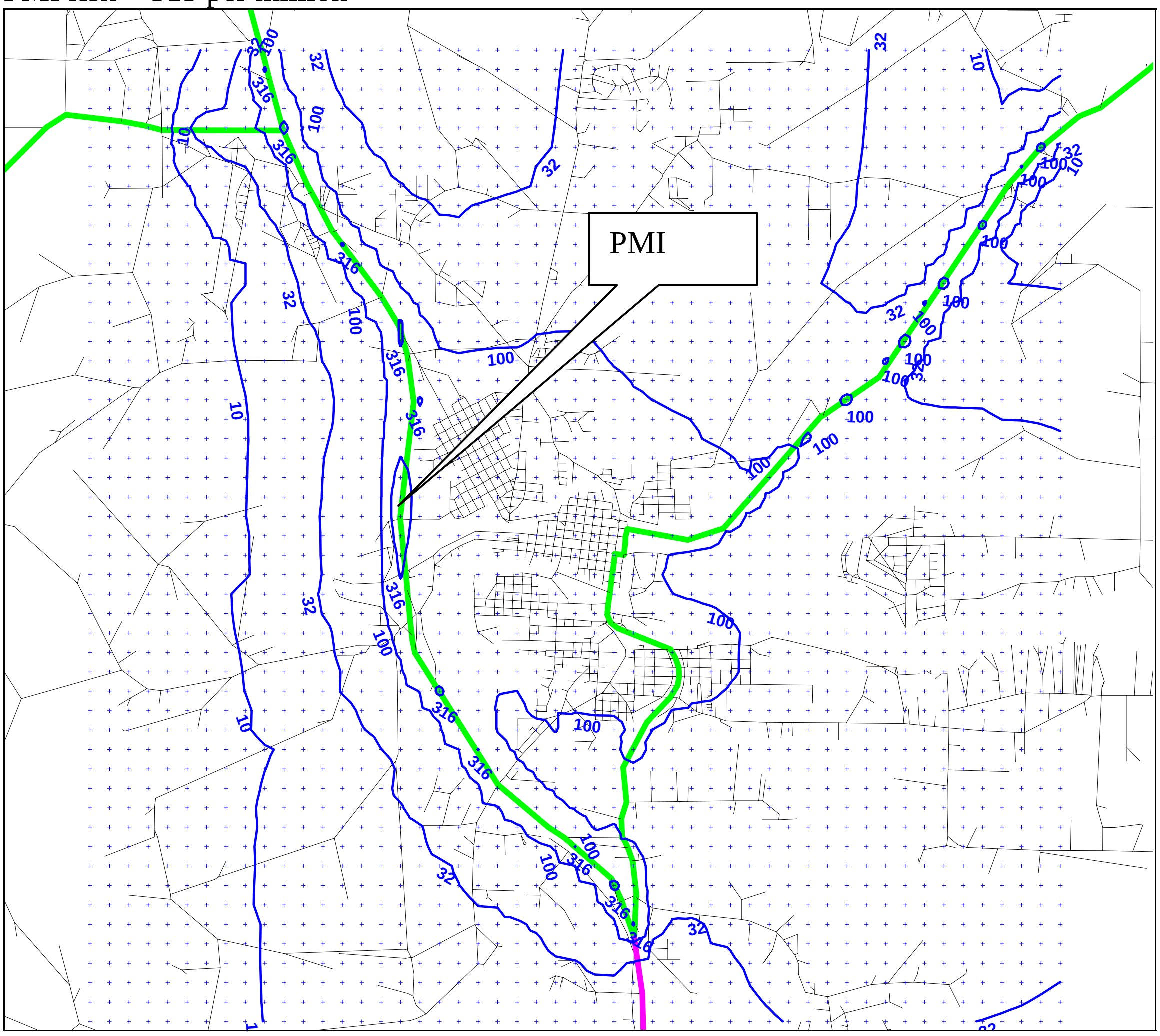
PMI risk = 218 per million



5.4.10.2.5 Total Cancer Risk

Figure 5-141. Shelton, all sources, cancer.

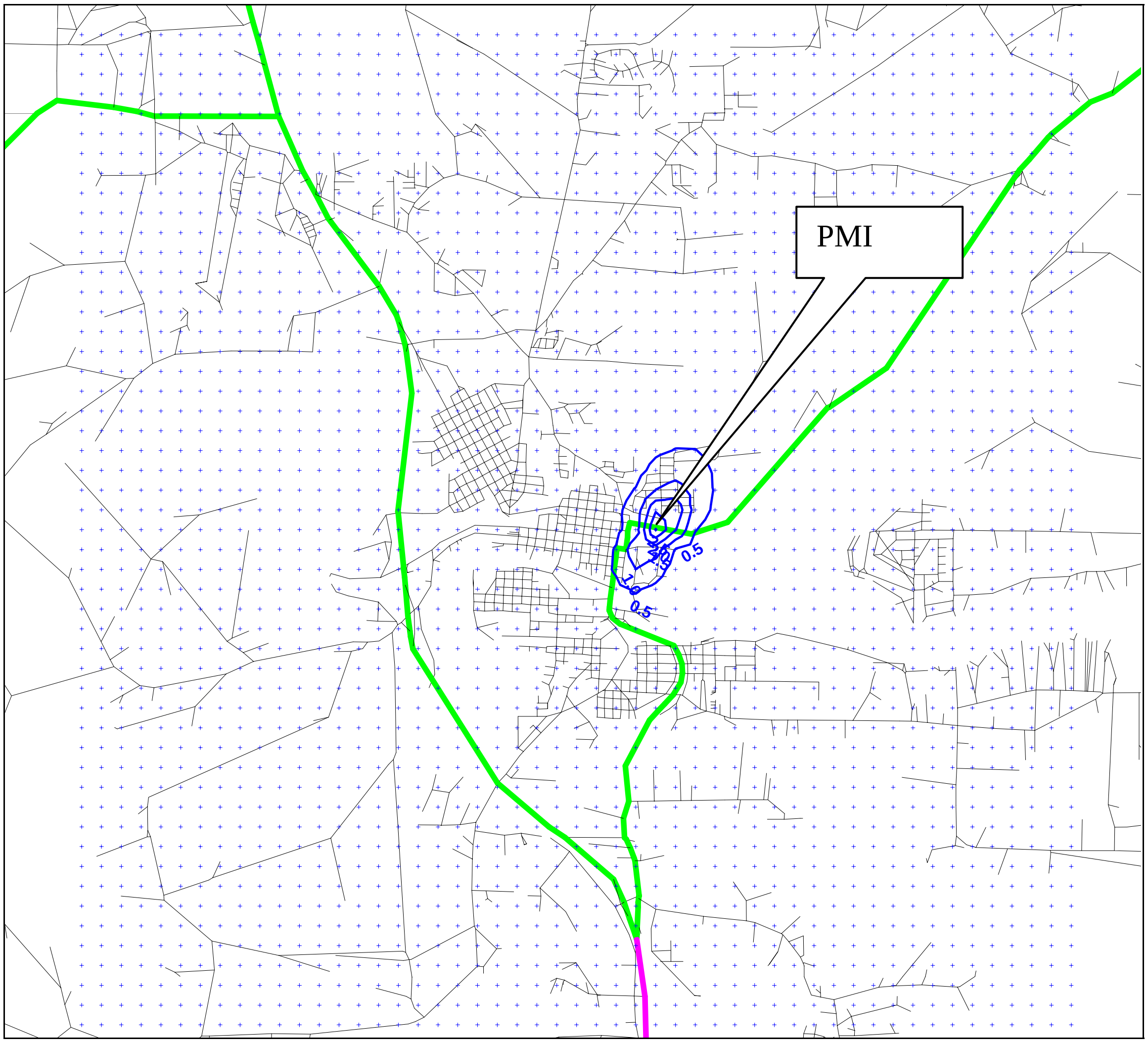
PMI risk = 515 per million



5.4.10.3 Chronic Non-cancer

5.4.10.3.1 Point Source (Commerical)

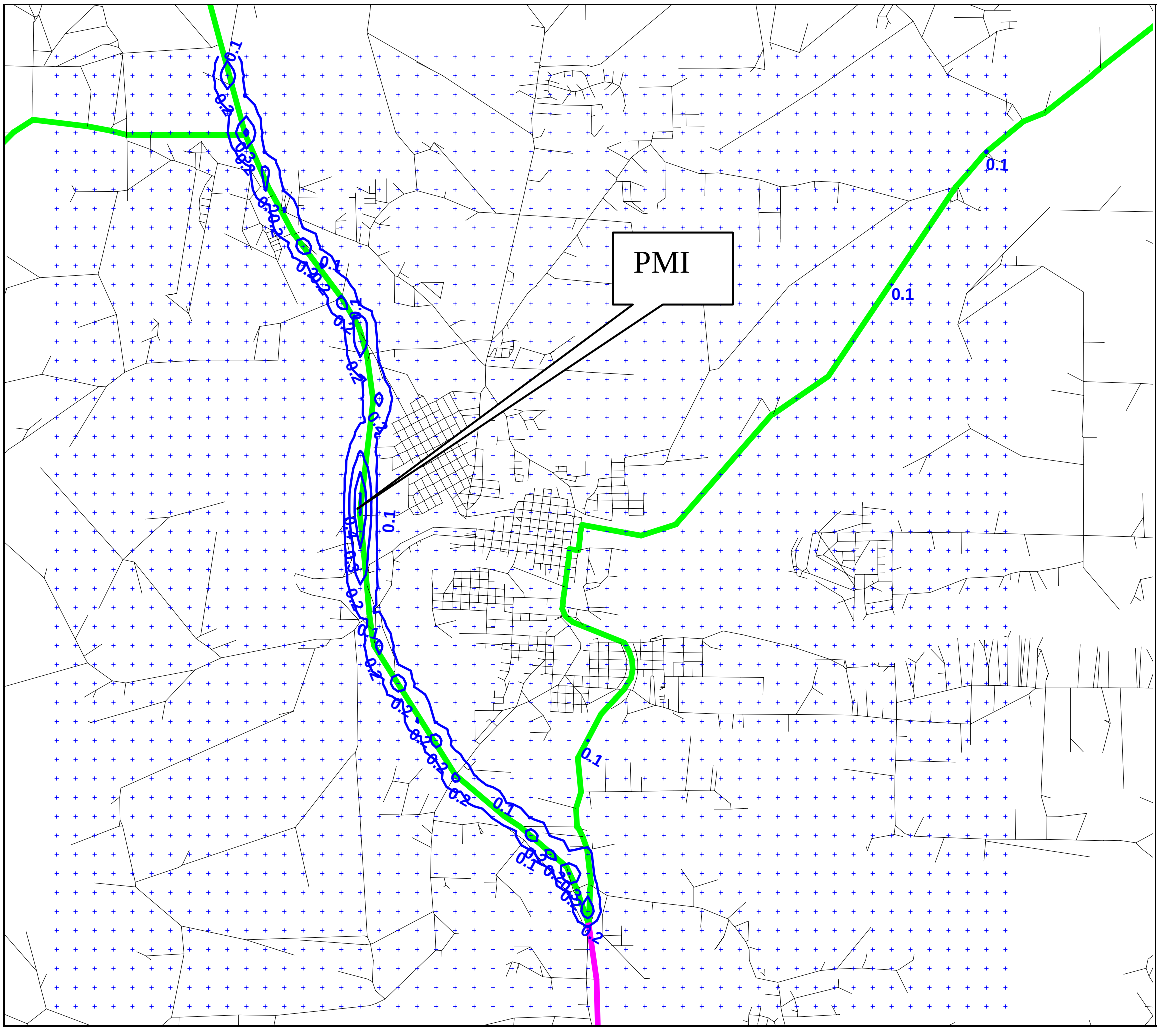
Figure 5-142. Shelton, commercial, chronic non-cancer HHI.
PMI risk = 2.52



5.4.10.3.2 Diesel On-road

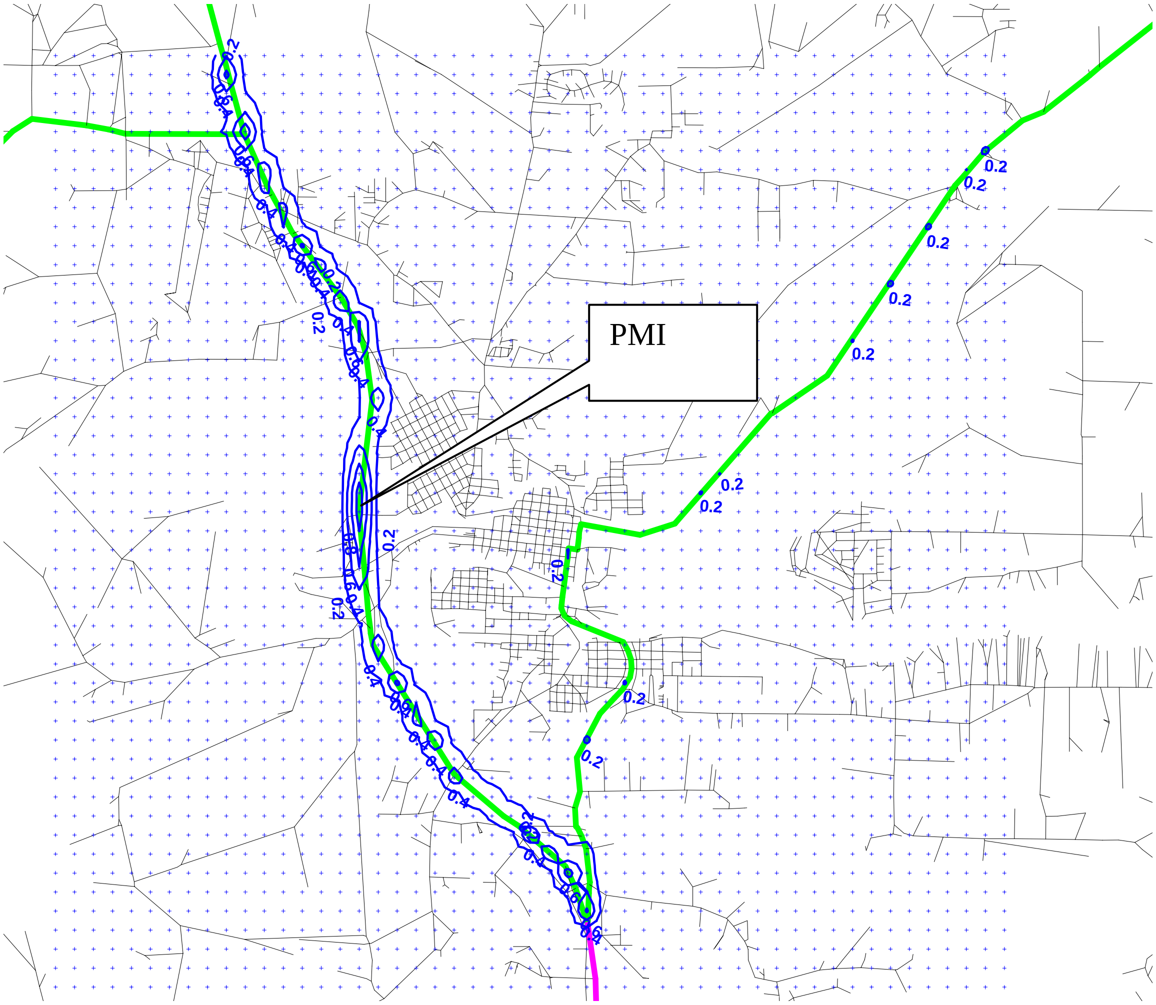
Figure 5-143. Shelton, on-road diesel, chronic non-cancer HHI.

PMI risk = 0.4



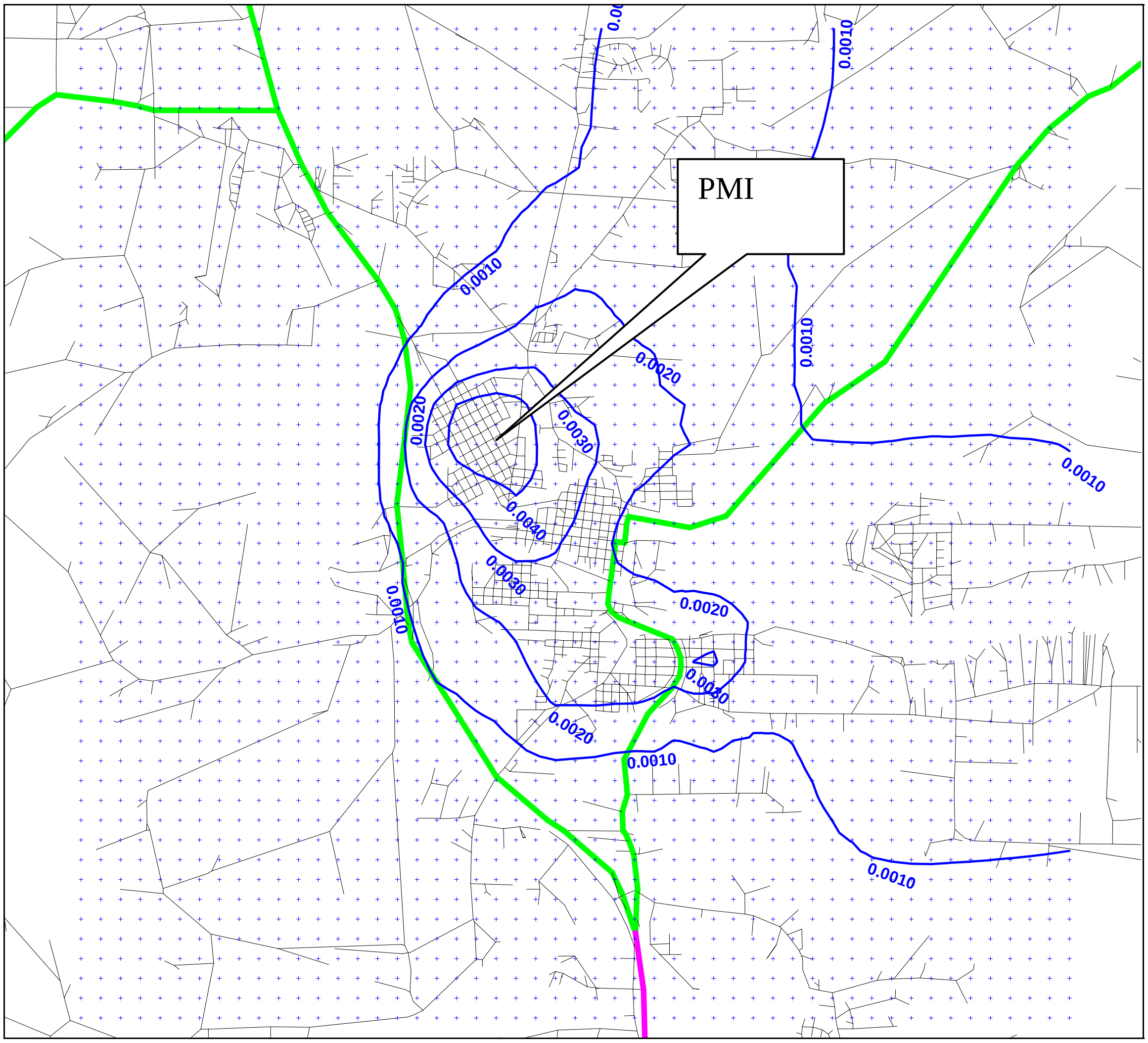
5.4.10.3.3 Gasoline On-road

Figure 5-144. Shelton, on-road gasoline, chronic non-cancer HHI.
PMI risk = 0.92



5.4.10.3.4 Wood Stoves and Fireplaces

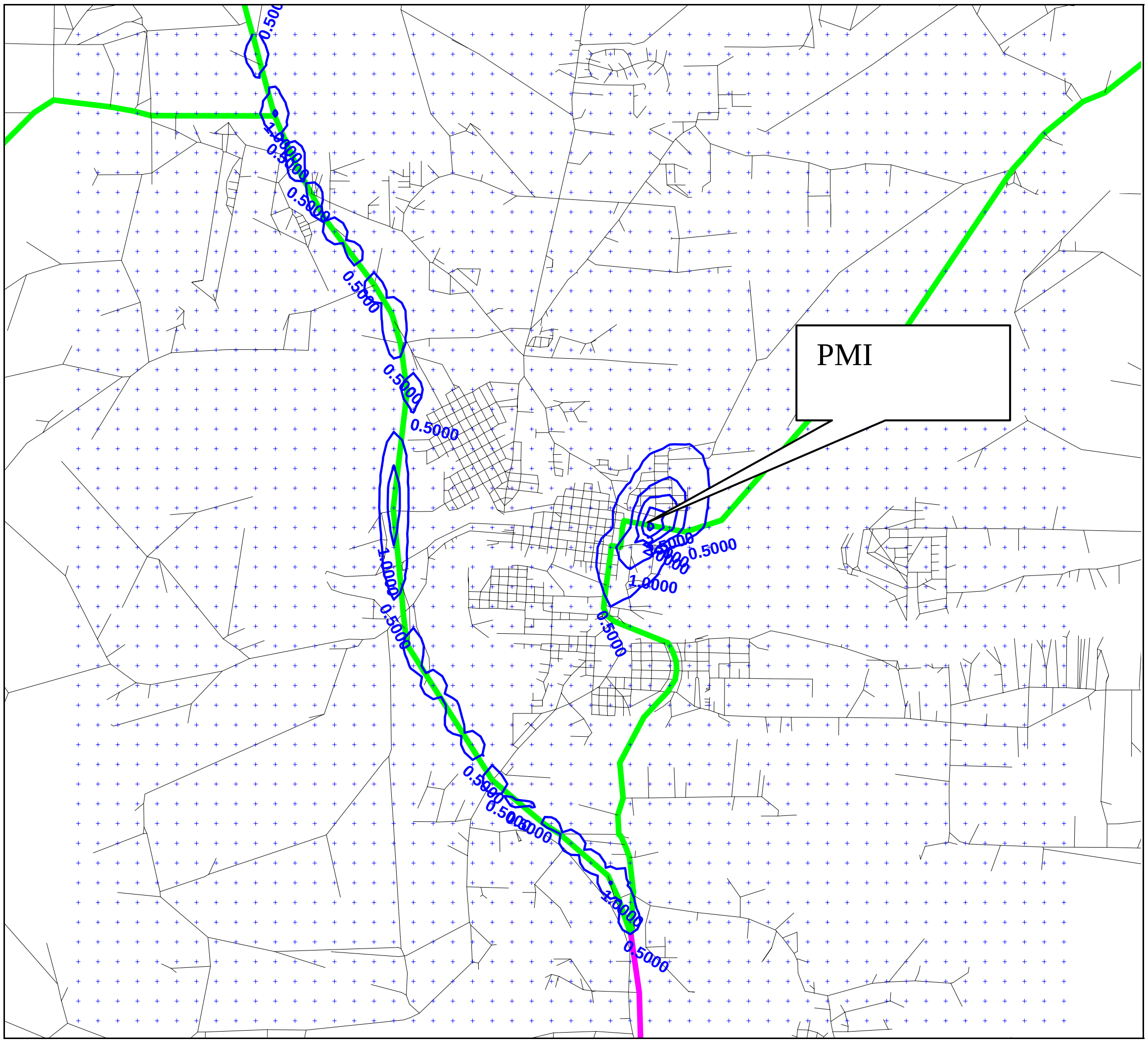
Figure 5-145. Shelton, wood stoves, chronic non-cancer HHI.
PMI risk = 0.0047



5.4.10.3.5 Total Chronic Risk

Figure 5-146. Shelton, all sources, chronic non-cancer HHI.

PMI risk = 2.68



5.4.11 Port Townsend

5.4.11.1 Summary

Figure 5-147. Port Townsend study area.

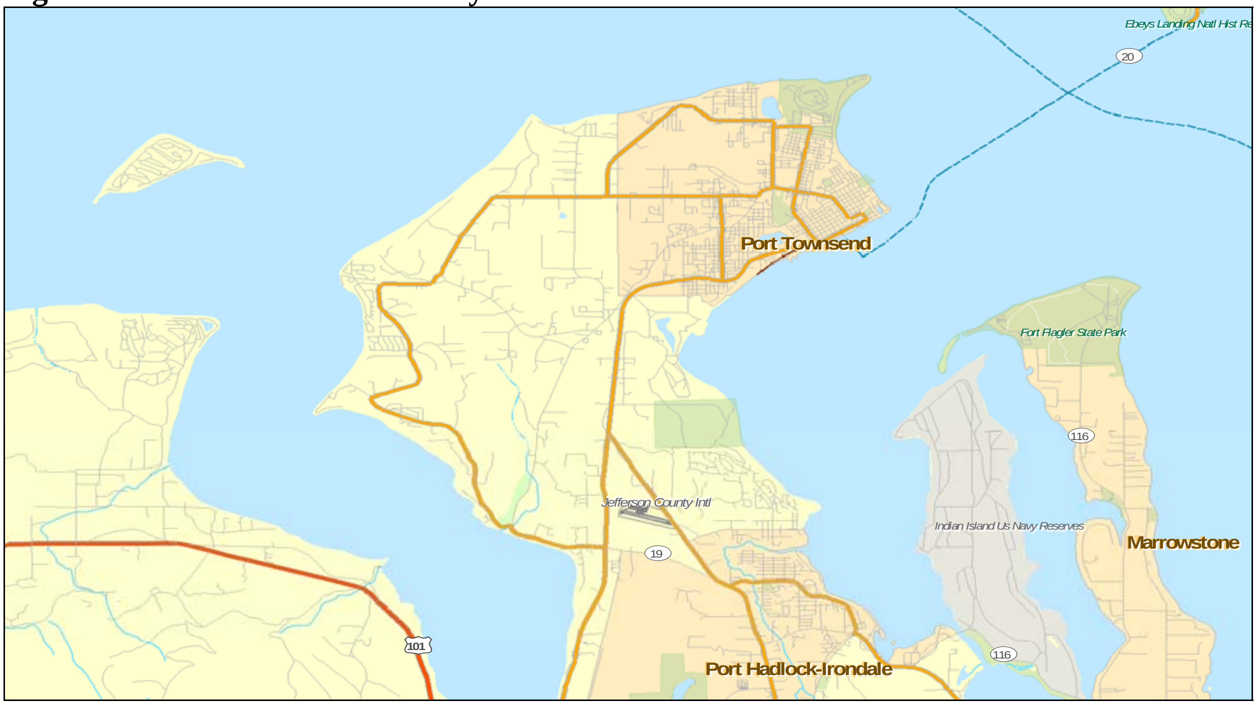


Figure 5-148. Analysis grid and locations of commercial sources. Source locations are indicated by circled X's.

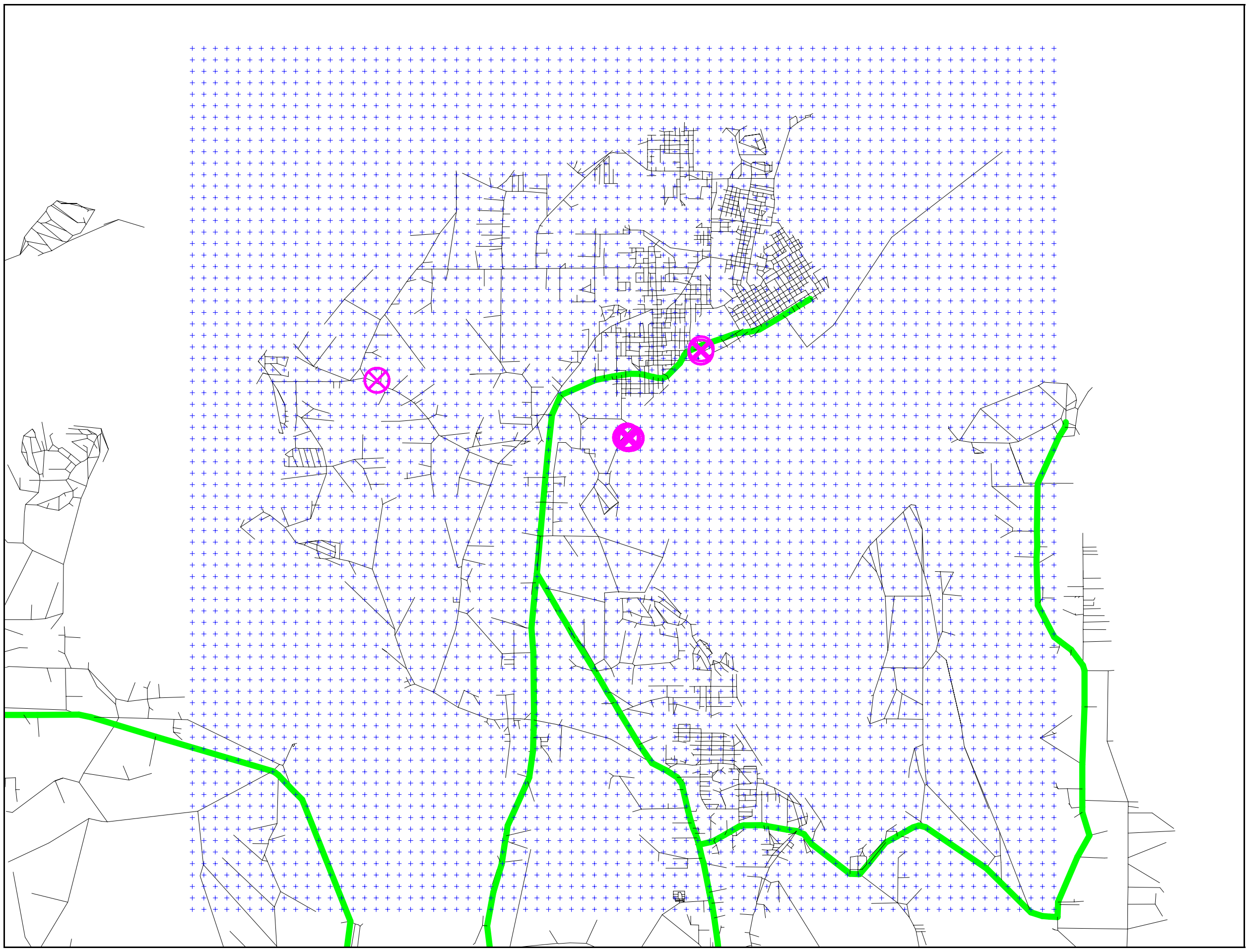


Figure 5-149. Locations of non-commercial sources.
Small magenta squares are locations of on-road freeway, artery, collector and local road sources. (Note that in Port Townsend there are no freeways) Green squares are the boundaries of local road area sources. Blue squares are locations of wood stove sources.

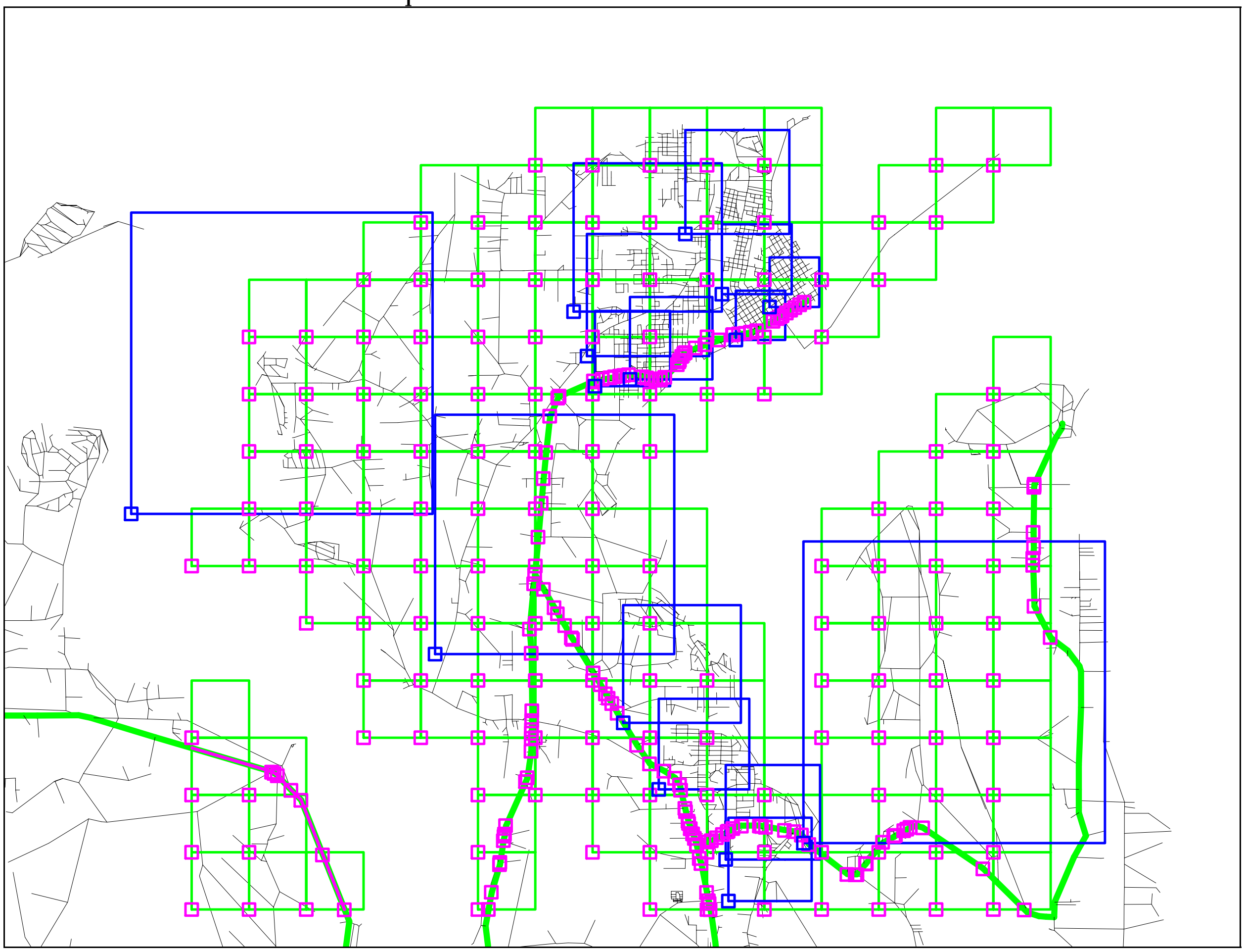
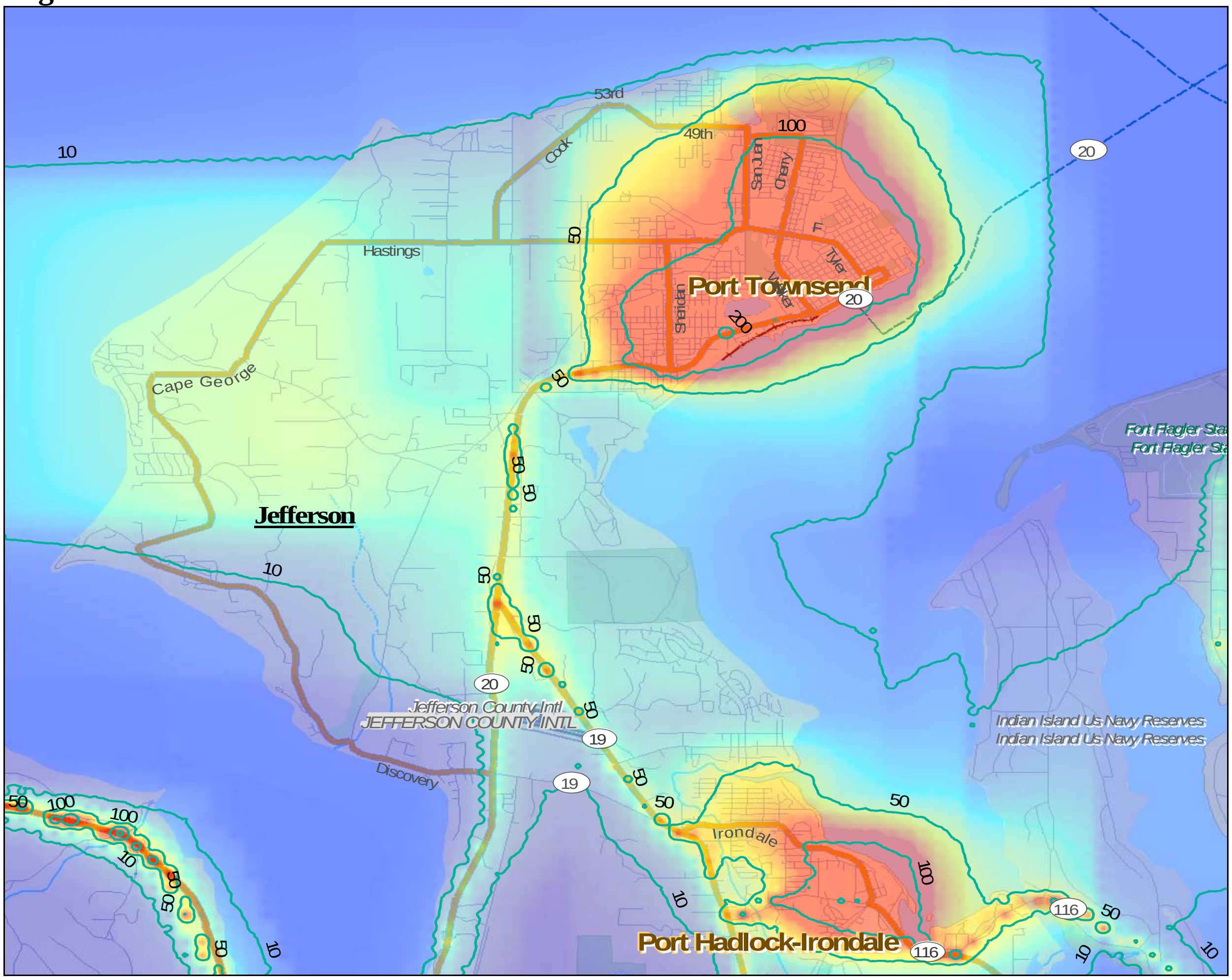


Figure 5-150. Contours of total cancer risk from all sources.



5.4.11.2 Cancer

5.4.11.2.1 Point Source (Commerical)

Table 5-34. Commercial sources included in this analysis.

Facility	***Stack***	***UTME***	***UTMN***
		meters	***meters***
PORT TOWNSEND PAPER COMPANY	stack 5433	515069	5326746
PORT TOWNSEND PAPER COMPANY	stack 54330	515142	5326708
PORT TOWNSEND FURNITURE CLINIC	stack 1931	516360	5328262
PORT TOWNSEND PAPER COMPANY	stack 54322	515062	5326712
PORT TOWNSEND PAPER COMPANY	stack 5434	515046	5326719
PORT TOWNSEND PAPER COMPANY	stack 5432	515131	5326704
TOWNSEND BAY MARINE	stack 301	516353	5328207
LAKESIDE INDUSTRIES - CAPE GEORGE	stack 651	510717	5327716
PORT TOWNSEND PAPER COMPANY	stack 54324	515081	5326700

Table 5-35. Chemicals dominating cancer risk.

CAS	POLLUTANT NAME	INHAL	DERM	SOIL	TOTAL
75092	Methylene chloride	2.01E-05	0.00E+00	0.00E+00	2.01E-05

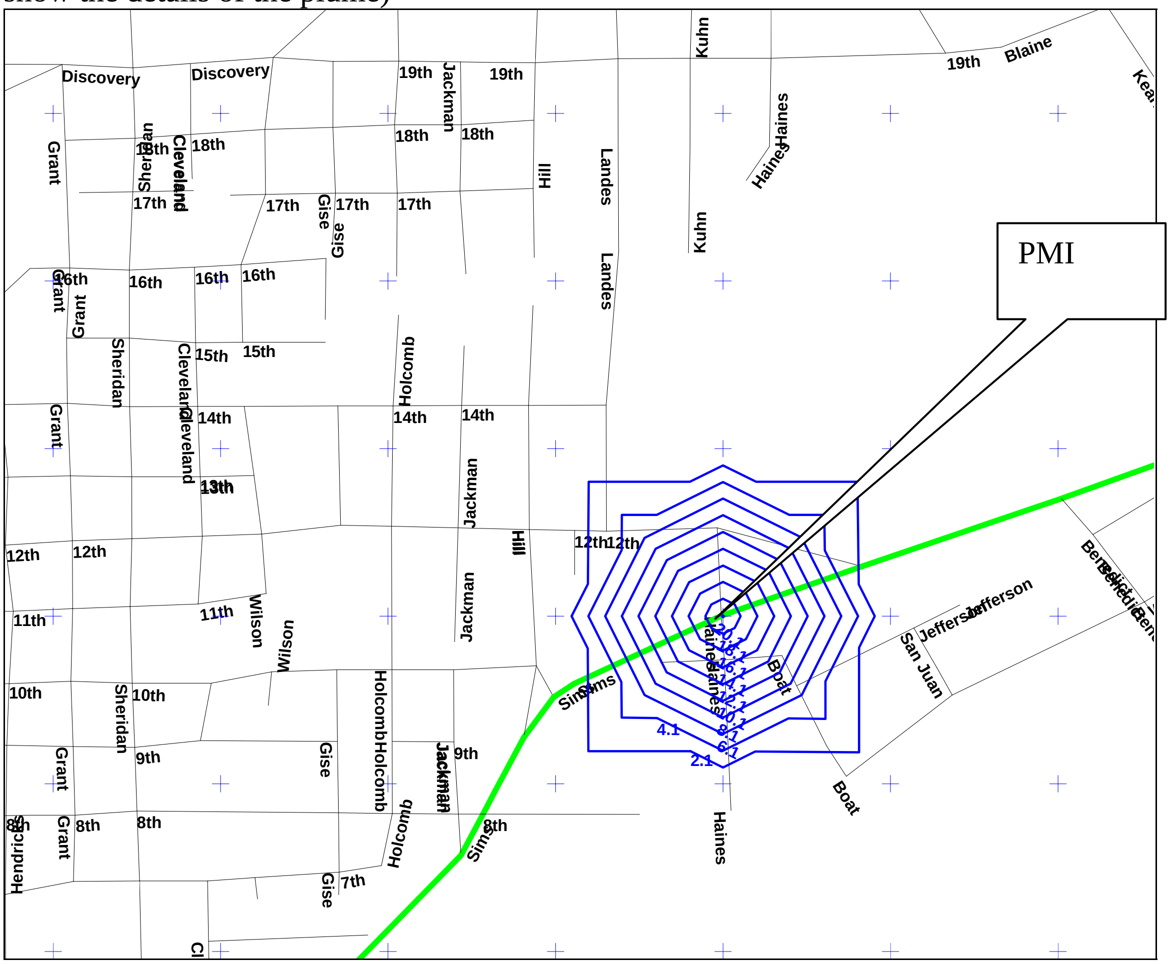
Table 5-36. Emissions of dominant chemicals.
Methylene chloride

Facility	Annual EMS (lbs/yr)
PORT TOWNSEND FURNITURE CLINIC	140

Figure 5-151. Port Townsend, commercial, cancer.

PMI risk = 20 per million

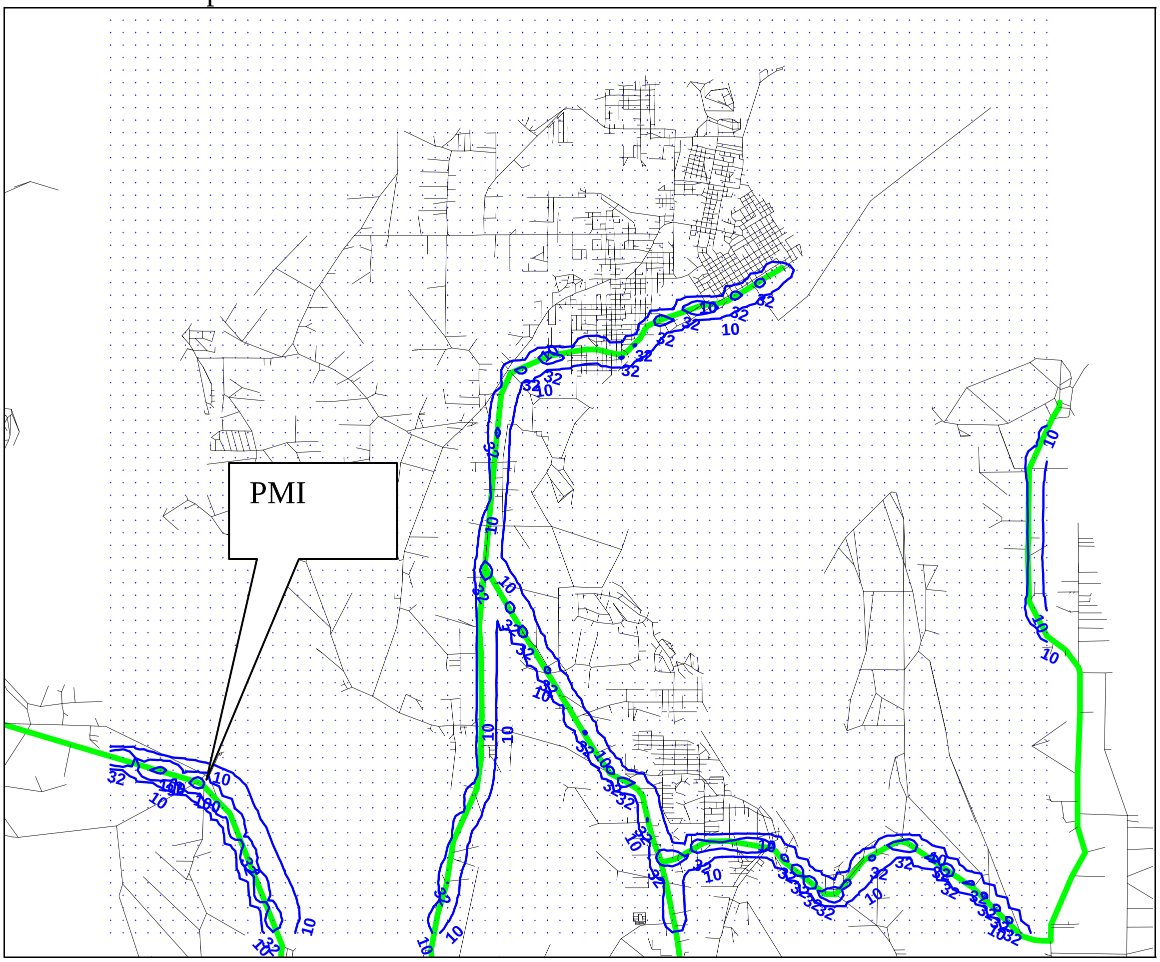
(Port Townsend Furniture has a very small, ground-level area source, which disperses less than 200 meters. The contours appear circular because the regional grid spacing is not fine enough to show the details of the plume)



5.4.11.2.2 Diesel On-road

Figure 5-152. Port Townsend, on-road diesel, cancer.

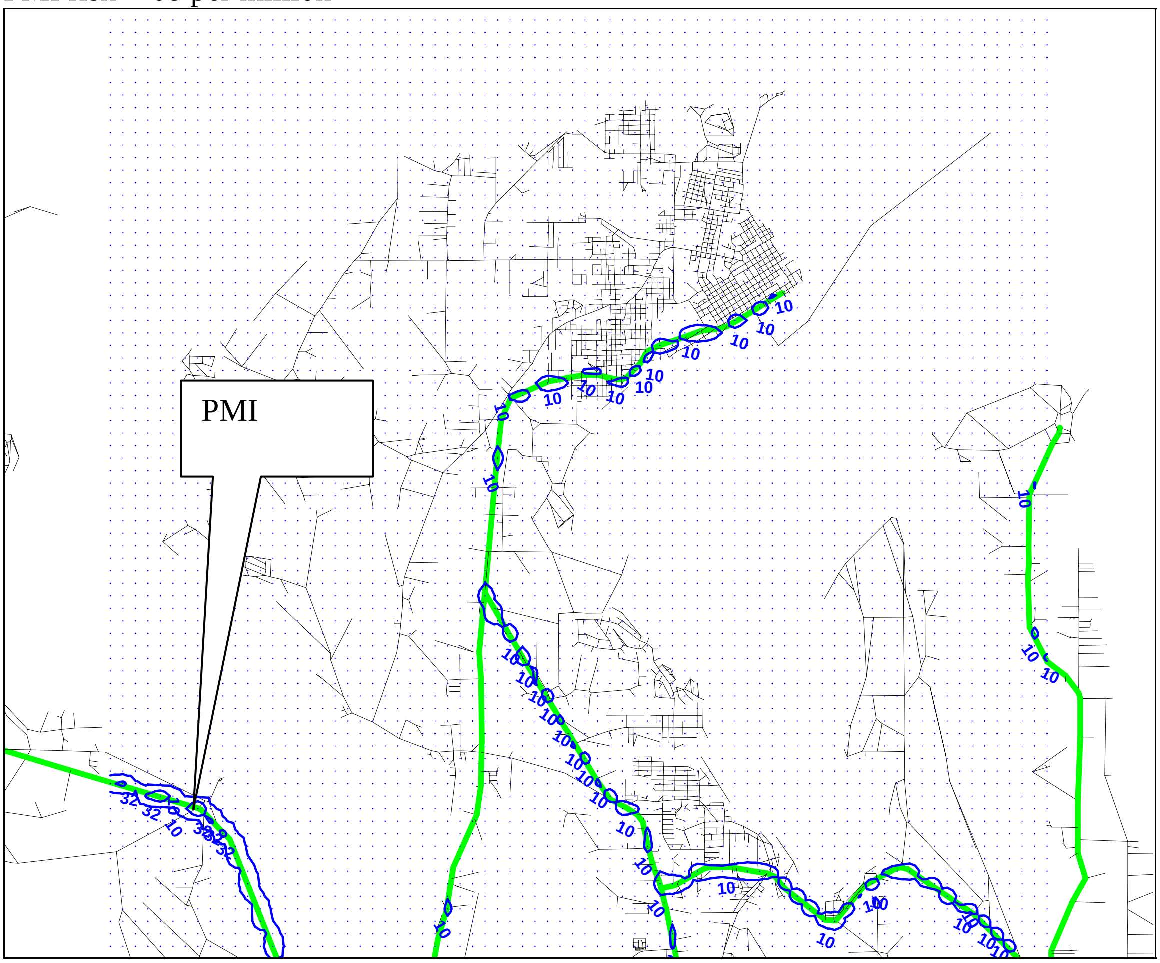
PMI risk = 170 per million



5.4.11.2.3 Gasoline On-road

Figure 5-153. Port Townsend, on-road gasoline, cancer.

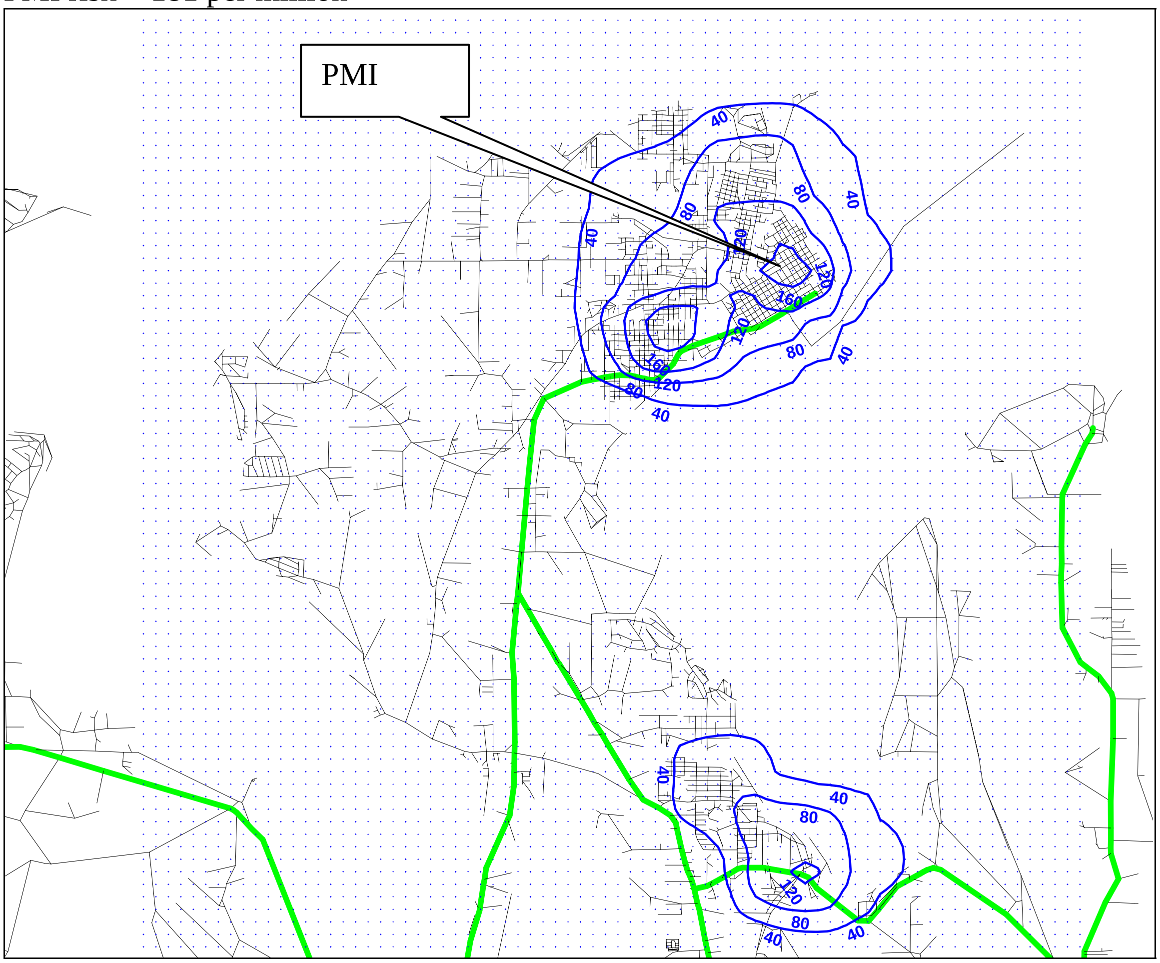
PMI risk = 68 per million



5.4.11.2.4 Wood Stoves and Fireplaces

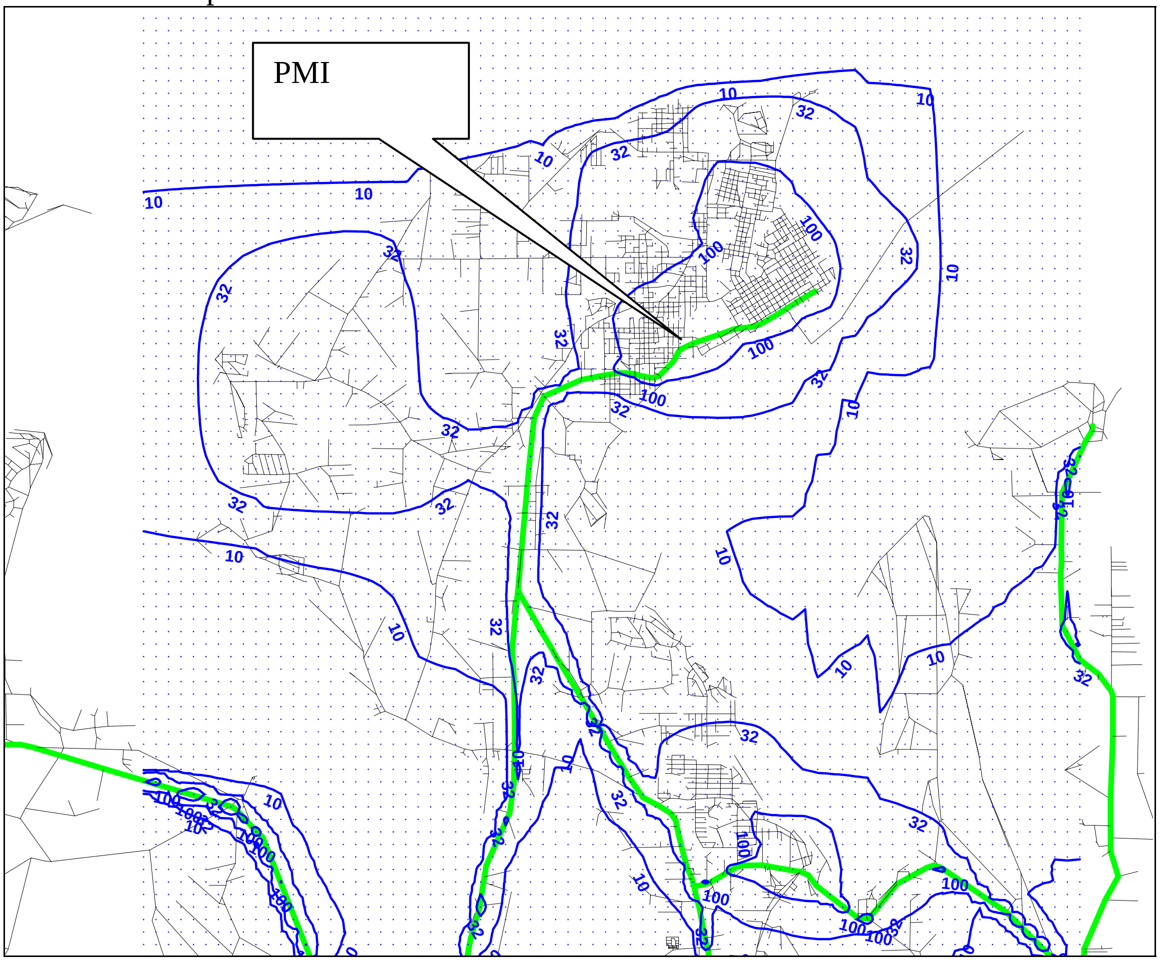
Figure 5-154. Port Townsend, wood stoves, cancer.

PMI risk = 181 per million



5.4.11.2.5 Total Cancer Risk

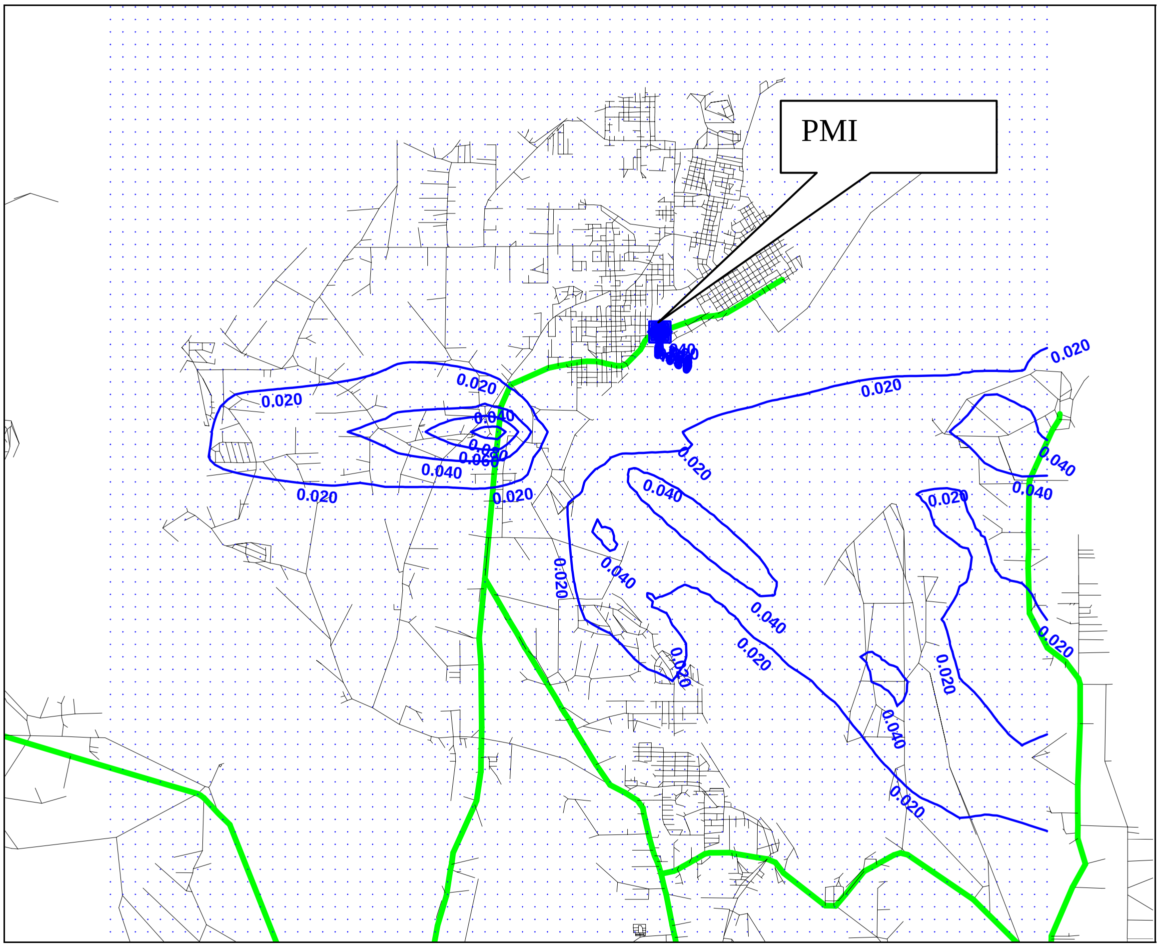
Figure 5-155. Port Townsend, all sources, cancer.
PMI risk = 244 per million



5.4.11.3 Chronic Non-cancer

5.4.11.3.1 Point Source (Commerical)

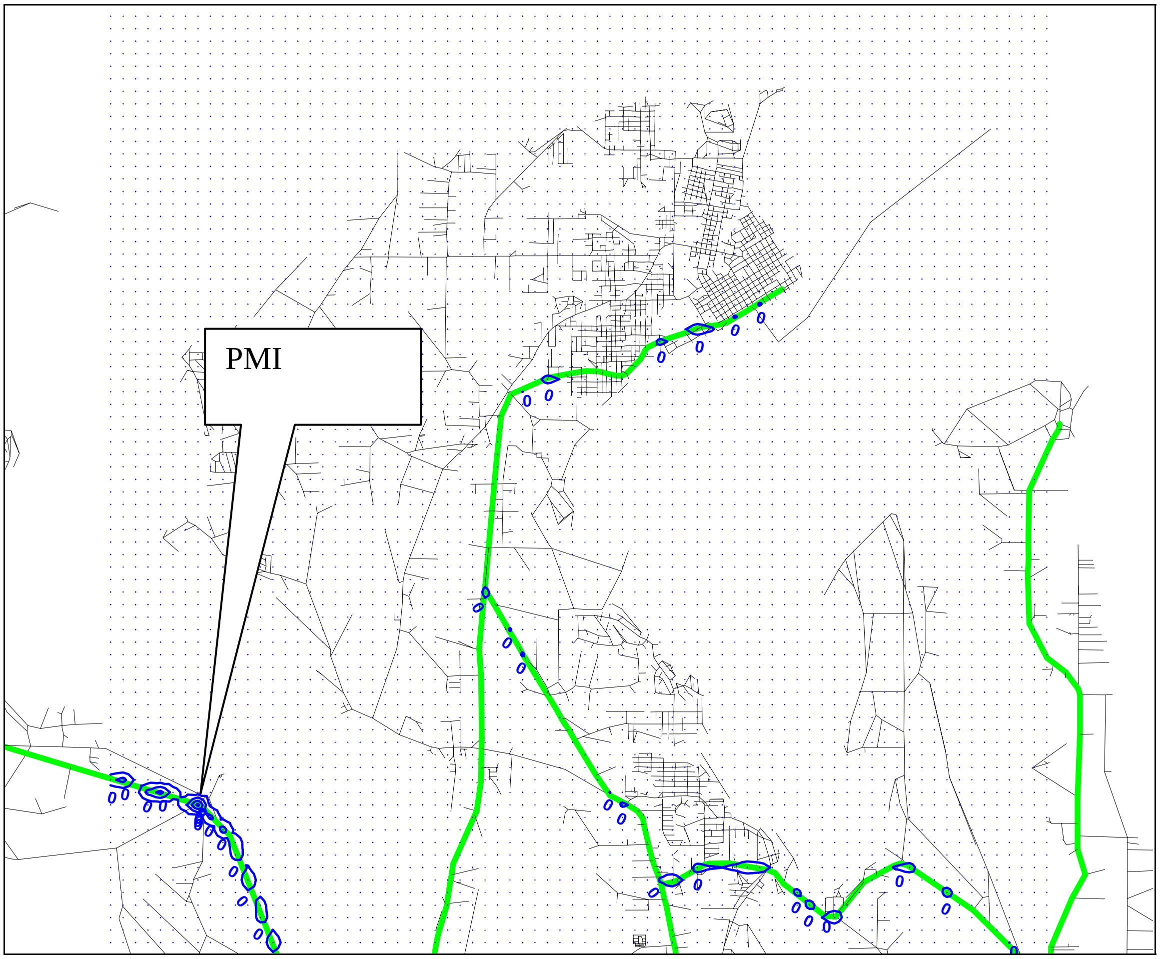
Figure 5-156. Port Townsend, commercial, chronic non-cancer HHI.
PMI risk = 0.23



5.4.11.3.2 Diesel On-road

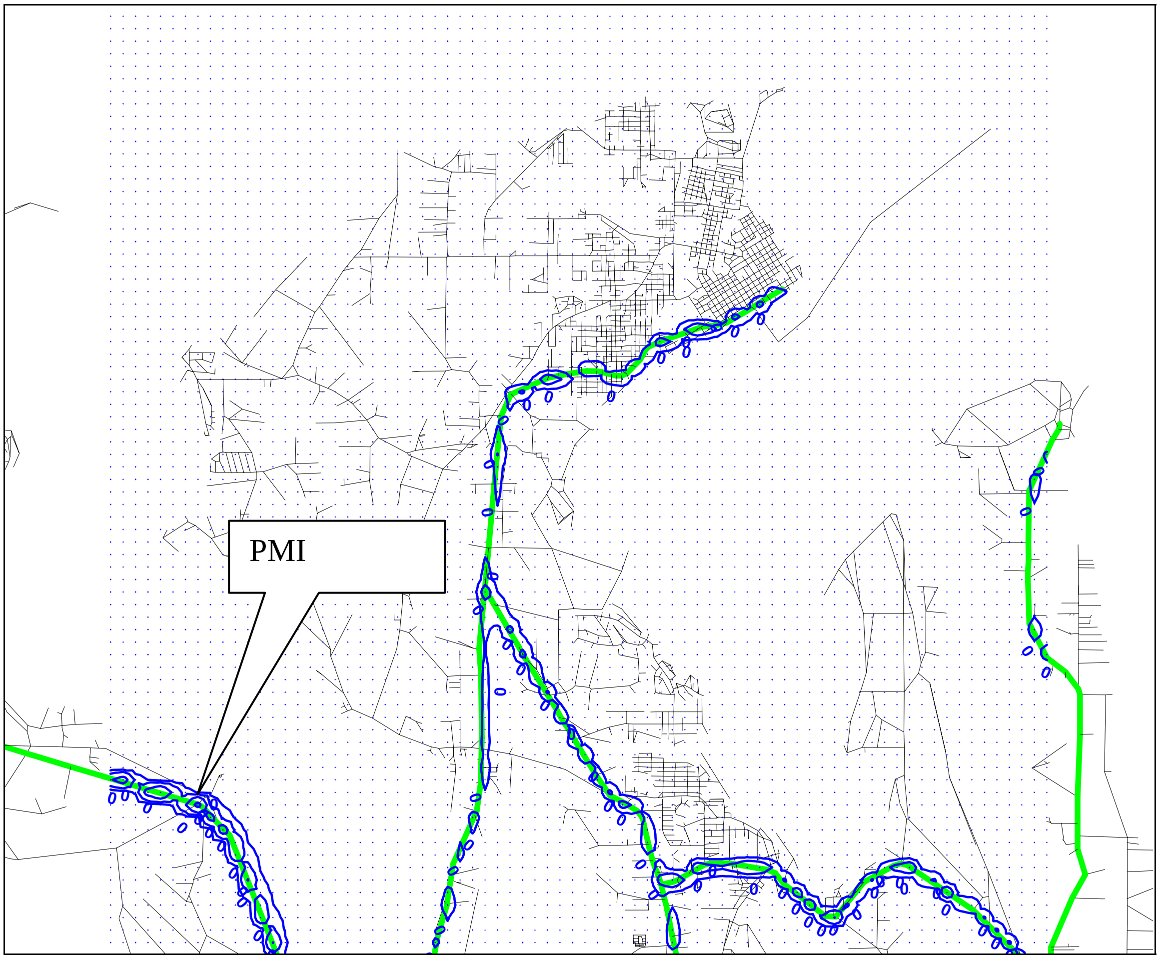
Figure 5-157. Port Townsend, on-road diesel, chronic non-cancer HHI.

PMI risk = 0.21



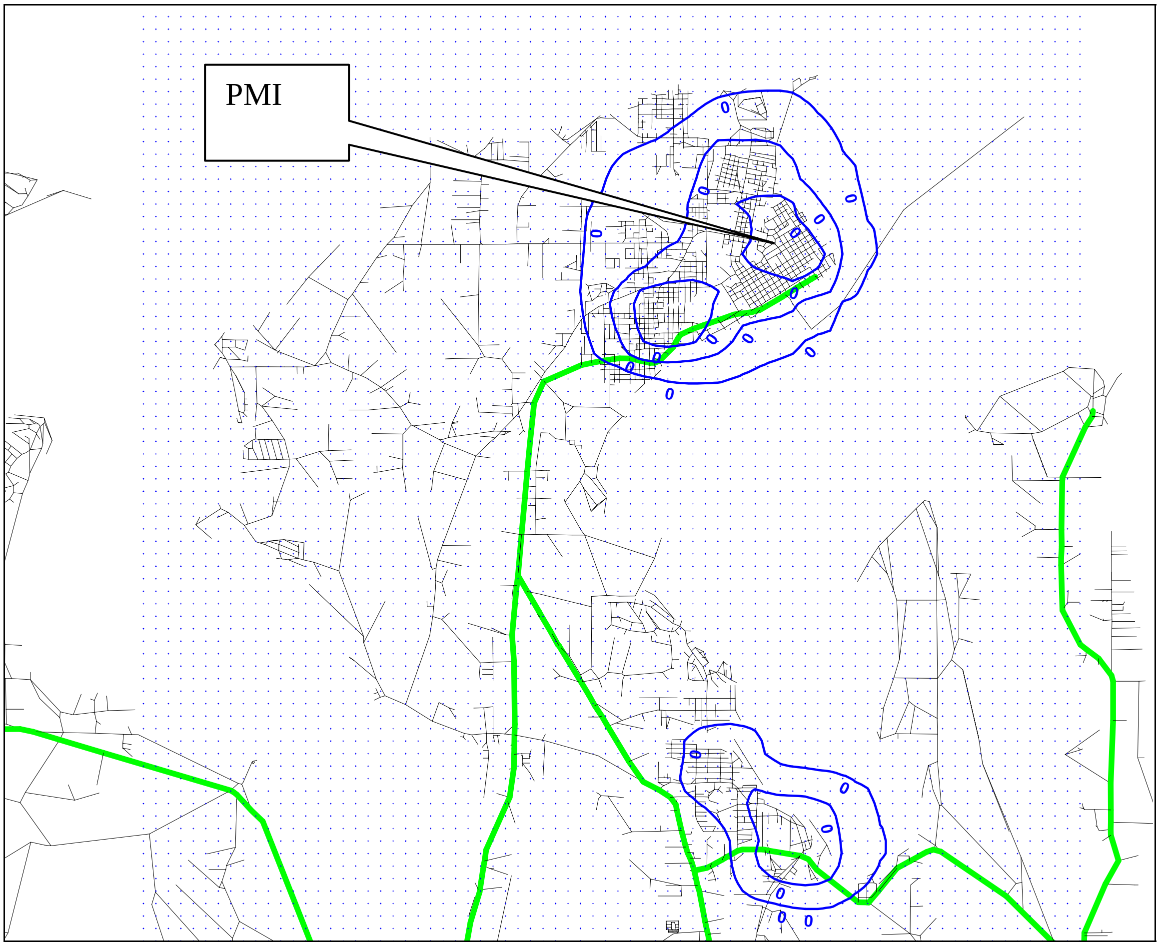
5.4.11.3.3 Gasoline On-road

Figure 5-158. Port Townsend, on-road gasoline, chronic non-cancer HHI.
PMI risk = 0.47



5.4.11.3.4 Wood Stoves and Fireplaces

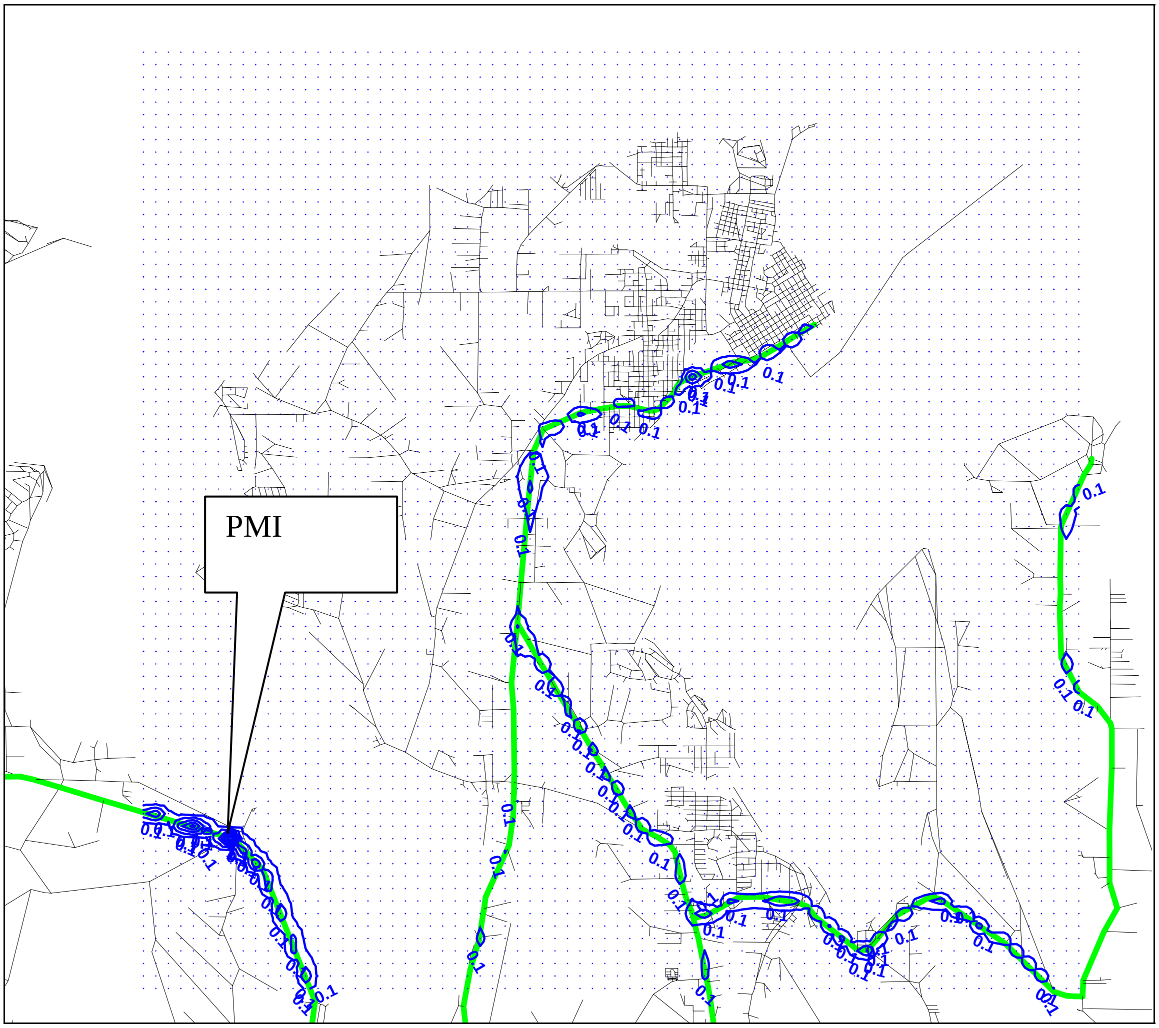
Figure 5-159. Port Townsend, wood stoves, chronic non-cancer HHI.
PMI risk = 0.0038



5.4.11.3.5 Total Chronic Risk

Figure 5-160. Port Townsend, all sources, chronic non-cancer HHI.

PMI risk = 0.695



6 Summary and Conclusions

Because there are 10 different study areas, it is not possible to draw detailed conclusions that apply to all of them. The reader is referred to section 5.4 for detailed results for each area. The following is a summary of the overall results.

<u>Cancer Risk</u>

- Cancer risk due to commercial sources ranges from 67 per million in Olympia to negligible levels in other areas. (see section 5.3.1.2)
- Cancer risk due to diesel on-road sources is typically in the range of 200-300 per million directly on the roadway, dropping off to 10 per million with in a few hundred meters of the roadway. Cancer risk due to diesel on-road sources is considerably higher in Olympia. (see section 5.3.1.3)
- Cancer risk due to gasoline on-road sources is typically in the range of 50-100 per million directly on the roadway, and drops off rapidly with increasing distance from the roadway. Cancer risk due to gasoline on-road sources is considerably higher in Olympia. (see section 5.3.1.4)
- Cancer risk from wood stoves is typically 100-300 per million when dermal and soil pathways are included. When only the inhalation pathway is included the risk is about 10-fold lower. Cancer risk from wood stoves is highest in Olympia. (see section 5.3.1.5)

<u>Chronic Non-cancer Risk</u>

- Chronic non-cancer risk due to commercial sources is below 1.0 except in Aberdeen and Shelton (see section 5.3.2.2)
- Chronic risk from on-road diesel sources exceeds 1.0 only for Olympia directly on the freeways (see section 5.3.2.3). Risk drops off rapidly with distance from freeway.
- Chronic risk from on-road gasoline sources exceeds 1.0 only for Olympia directly on the freeways (see section 5.3.2.4). Risk drops off rapidly with distance from freeway.
- Chronic risk from wood stoves is negligible in all areas (see section 5.3.2.5).

7 Appendices

7.1 Appendix - Wood Stove Data

The tables in this appendix list the census data used to develop the model of wood stove emissions described in this report.

Table 7-1. Total number of households that use wood fuel for heating in each of the counties in the study area.

County	*Number of households using wood fuel*
CLALLUM	3958
MASON	2998
THURSTON	6286
GRAYS HARBOR	3262
PACIFIC	1791
GRAYS HARBOR	3262
JEFFERSON	2157

Table 7-2. Wood stove emission sources. Each source is a census block group. The table shows the location and area of each source and the fraction of total county-wide wood stove emissions that are attributed to each source.

Clallum County

Tract	*Block Group*	*UTM East*	*UTM North*	*Area (m^2)*	*Number of households using wood fuel*	*Fraction of county total wood stove emissions*
980700	1	465749	5330715	2517495	46	0.0116
980700	2	463500	5330253	10013534	100	0.0253
980800	1	465895	5330131	952281	33	0.0083
980800	2	465554	5329609	1440725	88	0.0222
980800	3	465115	5328779	709254	12	0.0030
980900	2	467034	5328690	527511	23	0.0058
980900	3	466607	5329317	1132653	47	0.0119
981000	1	468430	5329088	948202	19	0.0048
981000	2	467756	5328612	859417	18	0.0045
981100	1	466734	5328051	868717	33	0.0083
981100	2	467702	5328033	392349	6	0.0015
981100	3	467358	5326259	9724884	47	0.0119
981200	1	469120	5328703	1564931	34	0.0086
981200	2	468629	5327176	2056449	36	0.0091
981200	3	469846	5327875	2985855	10	0.0025

Tract	Block Group	UTM East	UTM North	Area (m^2)	Number of households using wood fuel	Fraction of county total wood stove emissions
981300	1	470875	5328865	3843435	50	0.0126
981300	2	471936	5327371	3649827	60	0.0152
981300	3	473733	5327669	2453592	53	0.0134
981400	2	470155	5324110	34450174	176	0.0445
981400	3	475024	5324478	48575421	111	0.0280
981500	1	459408	5331159	15267552	71	0.0179
total					1073	0.2711

Mason County

Tract	Block Group	UTM East	UTM North	Area (m^2)	Number of households using wood fuel	Fraction of county total wood stove emissions
960600	1	489080	5230521	28154447	13	0.0043
960600	2	491026	5233014	12758279	12	0.0040
960600	3	493477	5233453	8946788	88	0.0294
960700	1	490881	5229762	920609	55	0.0183
960700	2	491204	5230068	1061690	24	0.0080
960800	1	492792	5230607	6897389	75	0.0250
960800	2	491875	5229566	747786	19	0.0063
960800	3	493106	5229284	4993186	20	0.0067
960800	4	491456	5228888	911084	30	0.0100
960900	1	493340	5227596	443635	29	0.0097
960900	2	492186	5227539	1766819	46	0.0153
960900	3	491443	5228208	2836202	34	0.0113
960900	4	492764	5227697	605946	5	0.0017
961000	1	490664	5224539	12858445	51	0.0170
961000	2	495792	5225105	26104049	128	0.0427
961000	3	496680	5227555	11644456	117	0.0390
961100	4	495730	5228694	5686705	37	0.0123
total					783	0.2612

Thurston County

Tract	Block Group	UTM East	UTM North	Area (m^2)	Number of households using wood fuel	Fraction of county total wood stove emissions
12410	1	529450	5198161	27767848	94	0.0150
12410	2	531818	5198639	7725250	64	0.0102
12410	3	530292	5200380	11484896	162	0.0258
10100	4	507822	5208866	725244	6	0.0010
10200	2	508776	5211229	738311	7	0.0011
10200	3	509890	5211288	3287628	42	0.0067

Tract	Block Group	UTM East	UTM North	Area (m^2)	Number of households using wood fuel	Fraction of county total wood stove emissions
10300	1	508602	5210126	1282666	22	0.0035
10300	4	510528	5210344	1371291	14	0.0022
10400	1	509181	5208553	2312566	15	0.0024
10400	2	507751	5207581	1309678	7	0.0011
10400	3	508209	5207200	398590	5	0.0008
10500	2	506155	5209942	618797	13	0.0021
10500	3	506044	5209431	2047656	8	0.0013
10600	2	505173	5211169	734704	9	0.0014
10600	3	505348	5210430	672703	6	0.0010
10600	4	506107	5210892	2017538	49	0.0078
10700	1	510964	5208321	2228786	6	0.0010
10700	2	510140	5209453	1769443	25	0.0040
10800	3	507313	5205647	3123653	15	0.0024
10800	4	506859	5204598	560452	12	0.0019
10800	5	507195	5203516	10191452	44	0.0070
10900	2	504885	5203779	5156624	69	0.0110
10900	3	504797	5206537	4495491	25	0.0040
10900	4	506700	5207320	658564	17	0.0027
10900	5	506596	5206609	3161616	50	0.0080
10900	6	505914	5205895	1174208	18	0.0029
11000	1	503173	5207947	14870599	22	0.0035
11000	2	501098	5204255	13286521	70	0.0111
11100	1	505492	5213063	2746133	24	0.0038
11100	2	503937	5212043	3973827	12	0.0019
11200	2	513212	5209092	1185006	21	0.0033
11200	3	515554	5210184	1457280	34	0.0054
11300	1	512378	5208065	1817590	14	0.0022
11300	4	513195	5207487	745657	17	0.0027
11410	1	513873	5208602	401962	33	0.0052
11410	4	514979	5208763	1279585	4	0.0006
11420	2	515023	5206848	2349133	35	0.0056
11420	3	516395	5206500	1513221	25	0.0040
11500	1	516903	5211684	1014859	11	0.0017
11500	3	516255	5210394	902496	11	0.0017
11610	1	516824	5209429	2522738	18	0.0029
11610	3	516851	5206599	1173598	9	0.0014
11620	1	513196	5205436	4528660	15	0.0024
11620	2	515731	5205012	2829600	26	0.0041
11620	4	517704	5204595	9332860	129	0.0205
11700	1	511086	5205821	3081681	24	0.0038
11700	2	509795	5206152	1180845	9	0.0014
11700	4	509471	5202201	6553208	45	0.0072
11700	5	512204	5201729	14823355	99	0.0157
11820	2	503629	5201624	4831407	34	0.0054

Tract	Block Group	UTM East	UTM North	Area (m^2)	Number of households using wood fuel	Fraction of county total wood stove emissions
11820	3	507400	5199750	9796625	50	0.0080
11900	2	501982	5217821	15195032	147	0.0234
12000	1	504706	5216875	9168925	67	0.0107
12000	2	501809	5212312	14100237	34	0.0054
12100	3	508592	5217352	5008399	65	0.0103
12100	4	508115	5213939	8310386	88	0.0140
12210	1	511595	5217560	12341519	73	0.0116
12210	2	512013	5213600	6249397	30	0.0048
12210	3	511542	5211363	4307612	36	0.0057
12210	5	513277	5211969	3303496	16	0.0025
12220	2	515240	5216652	13627992	57	0.0091
12220	3	516110	5213186	8870053	43	0.0068
12220	4	519022	5216198	27005748	53	0.0084
12310	1	520056	5209826	1492813	118	0.0188
12310	2	519212	5210335	3609063	55	0.0087
12310	3	519409	5207590	8176529	49	0.0078
12330	1	518634	5211225	2007453	25	0.0040
12330	2	518639	5212107	1154964	34	0.0054
12420	3	516793	5201694	8337365	68	0.0108
total					2653	0.4220

Grays Harbor County

Tract	Block Group	UTM East	UTM North	Area (m^2)	Number of households using wood fuel	Fraction of county total wood stove emissions
600	1	477255	5211304	40504286	116	0.0356
600	2	479690	5211202	1142392	30	0.0092
600	3	480358	5209420	58230556	38	0.0116
500	1	469037	5205707	1286108	45	0.0138
500	2	468665	5205980	1746951	43	0.0132
500	3	466718	5204955	20394754	18	0.0055
500	4	467289	5208191	94032363	108	0.0331
500	5	471796	5206888	19014732	74	0.0227
800	1	444892	5202603	7048745	58	0.0178
800	2	446265	5201312	36957616	108	0.0331
800	3	445848	5204286	42316760	29	0.0089
900	1	436400	5200070	4372739	37	0.0113
900	2	438647	5201880	428926	35	0.0107
900	3	439138	5202069	796974	14	0.0043
900	4	440141	5201969	1617149	35	0.0107
900	5	439750	5199989	15423269	85	0.0261
900	6	441170	5200493	1580860	41	0.0126

Tract	Block Group	UTM East	UTM North	Area (m^2)	Number of households using wood fuel	Fraction of county total wood stove emissions
1000	1	438386	5203429	559695	7	0.0021
1000	2	438995	5203824	4834897	22	0.0067
1000	4	437356	5202386	487856	7	0.0021
1100	1	436154	5203290	1763493	14	0.0043
1100	4	437239	5203919	917489	15	0.0046
1100	5	437998	5204856	1987653	25	0.0077
1200	2	435825	5202801	467285	43	0.0132
1200	3	436774	5202789	443874	7	0.0021
1200	4	437000	5202128	432335	5	0.0015
1200	5	436438	5202294	453564	55	0.0169
1300	1	435033	5206848	37159693	60	0.0184
1300	2	433802	5203044	2619358	23	0.0071
1300	3	433790	5202639	830230	13	0.0040
1300	4	434714	5202377	1777609	26	0.0080
1400	1	432367	5203950	1585410	17	0.0052
1400	2	431583	5205292	27464864	46	0.0141
1500	1	432464	5202794	1521215	13	0.0040
1500	2	430179	5203727	25494612	113	0.0346
200	2	412955	5201623	6573847	93	0.0285
200	3	411436	5201328	9600744	28	0.0086
1600	1	415266	5193575	7497276	54	0.0166
1600	2	415991	5191844	5574659	99	0.0303
1600	4	419136	5185805	62955711	72	0.0221
total					1771	0.54291845

Pacific County

Tract	Block Group	UTM East	UTM North	Area (m^2)	Number of households using wood fuel	Fraction of county total wood stove emissions
950200	1	439174	5175528	114416923	67	0.0374
950200	3	444335	5170431	3770506	47	0.0262
950200	4	442594	5169656	4854792	67	0.0374
950200	5	445983	5169316	7635268	85	0.0475
950300	3	438674	5168002	4497346	52	0.0290
950300	4	439936	5168578	1828682	71	0.0396
total					389	0.2172

Jefferson County

Tract	*Block Group*	*UTM East*	*UTM North*	*Area (m^2)*	*Number of households using wood fuel*	*Fraction of county total wood stove emissions*
950400	1	516448	5321392	2503549	53	0.0246
950400	2	517649	5320199	2720565	110	0.0510
950400	3	517601	5319377	2118904	19	0.0088
950400	4	520815	5322295	27724820	67	0.0311
950500	1	509075	5328042	27707165	226	0.1048
950500	2	513838	5325052	17456133	77	0.0357
950500	5	516063	5322788	4227386	10	0.0046
950601	1	517028	5331207	3297888	93	0.0431
950601	2	517368	5329858	1491665	66	0.0306
950601	3	518025	5329457	754327	26	0.0121
950601	4	517433	5328879	743777	16	0.0074
950601	5	515873	5328479	2067563	82	0.0380
950601	6	515199	5328298	1727106	48	0.0223
950602	1	515463	5330238	6715934	104	0.0482
950602	2	515470	5329234	4556748	45	0.0209
total					1042	0.4831

8 References

[1] Air Toxics Hot Spots Program Risk Assessment Guidelines, California Office of Environmental Health Hazard Assessment, Oakland, CA, August 2003

[2] Final Report: Puget Sound Air Toxics Evaluation, Puget Sound Clean Air Agency and Washington State Department of Ecology, October 2003.

[3] Washington State Base Year 2002 County Inventories, Washington State Department of Ecology, July 2004.

[4] Guideline on Air Quality Models, 40 CFR Part 51, Appendix W, as referenced in the Federal Register, Vol. 68, NO. 72, April 15, 2003.

[5] Turner, D.B., “Workbook of atmospheric dispersion estimates”, U.S. EPA Publication AP-26, revised 1970.

[6] Tiger/Line Files Technical Documentation, U.S. Census Bureau, U.S. Dept. of Commerce, 2000.