AN ASSESSMENT OF LUNG CANCER FROM THE 1984 TIRE FIRE IN EVERETT, WASHINGTON

On September 24, 1984 a fire broke out in a scrap tire dump east of Everett which contained more than a million tires. The tires burned for more than two months. The Puget Sound Air Pollution Control Agency requested that EPA perform a risk analysis using data gleaned from selected ambient particulate matter samples from stations in Everett and North Seattle operated by that agency. These samples were analyzed for selected products of incomplete combustion (including benzo(a)pyrene). These data coupled with emission parameter estimates were then used to estimate risk to the exposed population. This document presents the results of the risk analysis.

October, 1986

U.S. Environmental Protection Agency
Region 10
1200 Sixth Avenue
Seattle, Washington 98101

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION 10
1200 SIXTH AVENUE
SEATTLE, WASHINGTON 98101

OCT 8 1986

REPLY TO ATTN OF M/S 532

Mr. Arthur Dammkoehler
Air Pollution Control Officer
Puget Sound Air Pollution Control Agency
P.O. Box 9863
Seattle, WA 98109

Dear Mr. Dammkoehler:

As you requested in your letter of November 20, 1985, we have evaluated the long term health risk from the Everett tire fire. We have confined our health assessment to estimating the increased cancer risk from inhalation exposure to airborne particulates emitted during the fire. The specific contaminants evaluated were benzo(a)pyrene (B(a)P) and a class of compounds called Products of Incomplete Combustion (PIC). Attached is a report summarizing the results of that assessment.

Using EPA risk assessment methods, the analysis indicated that those individuals (4 of them) calculated to have the highest exposure to the tire fire emissions may have an increased lung cancer risk from 2 in one million to 2 in ten thousand. Since exposure for other residents living in the vicinity of the fire was less, their estimated lung cancer risks are also less (substantially less for most).

Because of the methodologies used these estimates represent a likely upper bound of lung cancer risk - the actual risk is somewhere between zero and these numbers. It should also be stressed that there are many uncertainties and assumptions involved in deriving these lung cancer estimates. These are summarized in the report.

The U.S. EPA has not defined a cancer risk level which is considered to be significant. However, excess cancer risk levels above 1 in a million to 1 in 100,000 (10^{-6} to 10^{-5}) generally give some cause for concern and suggest that exposures should be reduced. To put these numbers in perspective, however, a lung cancer risk of 10^{-6} to 10^{-5} is equivalent to smoking about 5 to 50 cigarettes in a lifetime.

We appreciate the support your staff provided in performing this assessment. Should you have any questions about the results or methodologies, please contact Dana Davoli at 442-1757.

Sincerely,

George Alec for

Gary O'Neal, Director
Air and Toxics Division

Attachment

cc: Dave Peterson, Snohomish Health District

On September 24, 1984, a tire fire began burning at the old City of Everett Landfill in Everett, Washington. During the first few weeks of the fire large quantities of smoke were released. This fire continued to smolder for about two months emitting smoke at gradually decreasing levels. The City of Everett, which is west of the fire, was at times heavily impacted by the plume. Smoke was also dispersed to the east and to the south toward Seattle.

Limited air monitoring for organic vapors was done around the tire fire by the U.S. Environmental Protection Agency's (U.S. EPA) Technical Assistance Team on September 28, 1984. ("Tire Fire Investigation, TAT Activities Report", U.S. EPA, Region 10, October, 1984). The results from this one day of monitoring showed that high levels of some compounds (e.g., benzene) were present in or very near the fire but dropped off rapidly in concentration within a half mile. At the request of the Snohomish Health District, the Centers for Disease Control (CDC) reviewed these data. CDC concluded that "concentrations of some chemicals in the immediate vicinity of the fire were high enough to pose a potential immediate health threat to individuals within 200 feet of the fire." Personnel at the scene of the fire (e.g., firemen) were of most concern. Persons living beyond the immediate area of the fire may have received transient exposure, according to CDC, resulting in a "temporary increased risk of acute short term health effects" (e.g., respiratory impairment; eye, throat and respiratory irritation). CDC also stated that "we do not anticipate any significant increased risk of long term health effects nor can we conclude that chemicals in the smoke reached the public in sufficiently high concentration to significantly affect health."

The Puget Sound Air Pollution Control Agency (PSAPCA) has monitors located in Seattle and Everett to measure levels of particulates in the air. A sample collected from the Everett monitor on September 28, 1984 (about 1.2 miles from the fire) was analyzed for selected particulate organics by a lab at the University of Washington in January,1985. The results showed levels of polycyclic aromatic hydrocarbons (PAHs) that were above background. Several members of this class of compounds are known or suspected of causing cancer. At the request of PSAPCA, the U.S. EPA's Region 10 laboratory analyzed 24 additional samples collected by PSAPCA at the Everett station and at two stations in Seattle (approximately 20 and 25 miles south of the tire fire) during the first few months after the tire fire began. These results also showed elevated levels of PAHs in Everett and at both Seattle locations during the fire which lasted about 2 months. Because of these results PSAPCA requested that EPA quantitatively "assess the long-term health risk from the tire fire emissions."

In response to PSAPCA's request, EPA has estimated the lung cancer risk that may result from emissions of benzo(a)pyrene (B(a)P) and Products of Incomplete Combustion (PIC) from the fire. B(a)P is a polynuclear aromatic hydrocarbon (PAH) that is a suspected human cancer causing agent (carcinogen). PICs are loosely defined as a complex mixture of compounds which includes PAH (polynuclear aromatic hydrocarbons) and possibly other organic compounds that are released during the combustion of organic material.

We limited our risk analyses to B(a)P and PIC for several reasons:

(1) Although increased levels of particulates were detected on PSAPCA's samplers more than a mile from the tire fire, the limited sampling data collected by EPA for gaseous organics suggest that levels of these gaseous compounds dropped off quickly within a short distance of the fire. CDC concluded from these data that these gaseous organics did not reach the public in sufficiently high concentrations to cause a long term health risk.

(2) Although other particulate organics were detected on PSAPCA's samples, toxicity and potency (unit risk numbers) data are available only for B(a)P and the generic class of incomplete combustion products, PICs. (see below).

(3) Data from the literature are available to make rough estimates of the amounts of B(a)P emitted from the fire. These data were used in a computer dispersion model to estimate ambient air exposure for residents in the Everett-Seattle area. These modeled ambient air results could also be compared to those levels measured by PSAPCA.

The scientific data now available make it extremely difficult, if not impossible, to identify a level of exposure to cancer-causing agents that is safe. Therefore, EPA and other federal agencies have taken the position that cancer may occur at any level of exposure no matter how low. EPA has also assumed that the risk of cancer increases as exposure increases and that this relationship is linear (e.g., when exposure doubles so does risk). Thus, although a "safe" exposure can't be defined, estimates can be made of the risk of getting cancer if exposure to a cancer-causing substance is known. To estimate the risk from the tire fire, EPA has combined two different types of data: data on the B(a)P exposure for the populations living within about 30 miles of the fire and data on the cancer potency of B(a)P and PIC.

As a first step in calculating exposure levels, emission levels of B(a)P from the fire were estimated from data on the number of tires consumed during the fire and from literature data on the amounts of B(a)P released per pound of burning tire. A mathematical (dispersion) model used these emission data as well as data on weather and geographic conditions to estimate the concentrations of B(a)P at about 250 points around the fire within a 30 mile radius. This information was then combined with Bureau of Census population figures to provide an estimate of the number of people exposed to a given level of B(a)P (see the Attachment for a more detailed explanation of this methodology).

The other type of data needed to estimate the public lung cancer risk from the fire is that on the potency of B(a)P-this potency is expressed as a unit risk number. The unit risk number is defined as the lifetime cancer risk that would occur in a population which is exposed throughout their lifetime (70 years) to one microgram per cubic meter of B(a)P in the air they breathe. The unit risk number for B(a)P, which was derived using experimental data on animals, is about 3×10^{-3} per ug/m^3 (micrograms of B(a)P per cubic meter of air).

The unit risk number for B(a)P and the estimated B(a)P exposure for people living around the fire site were multiplied to give the estimated lung cancer risk if exposure to the fire had occurred for 70 years (over an entire lifetime). This risk number was then divided by 420, the number of two month periods in 70 years, to adjust it for the fact that exposure occurred only for the tire fire duration (i.e., about 2 months). For the persons with the highest exposure to B(a)P emitted by the tire fire, their increased lifetime cancer risk is approximately 2×10^{-6}. That is, their estimated risk of getting cancer as a result of the fire is 2 in 1 million (see Table 3 in the Attachment). This risk decreases significantly as distance from the fire increases.

This level of risk could be compared to the average expectation of dying of all types of cancer which is about 1 in 5 and the lifetime risk of dying from lung cancer for cigarette smokers (pack a day) which is about one in 10. Another way of stating this is that a risk of 2×10^{-6} is equivalent to smoking about 10 cigarettes over a lifetime.

Another way of estimating risk from exposure to B(a)P utilizes a different unit risk number, that for Products of Incomplete Combustion or PIC. During combustion of organic material many compounds in addition to CO_2 and water can be released because the combustion is not 100% efficient and because of impurities in the materials being burned. These may include the original organic material or other more or less complex compounds formed during combustion. As previously mentioned, this complex mixture of compounds is loosely defined as PIC and includes PAH (polynuclear aromatic hydrocarbons) and possibly other organic compounds.

A unit risk number for PIC has been derived using B(a)P as a surrogate. As an example, workers exposed to products of incomplete combustion (e.g., roofers, gas workers) have higher lung cancer rates than non-exposed workers. Although PICs are a complex mixture of compounds, most of the worker exposure data are expressed in B(a)P concentrations since B(a)P is a suspected carcinogen and is fairly easy to measure. Therefore, in these studies, B(a)P serves as a surrogate or indicator of the PICs, and cancer risk is expressed in excess cancers per unit measure (e.g., ug/m^3) of B(a)P. Results from many studies such as these (occupational and non-occupational) were combined to estimate the PIC unit risk number. The B(a)P exposure levels estimated to be produced as a result of the tire fire can be used with the PIC unit risk number (4×10^{-1} per ug/m^3) to estimate lung cancer risk resulting from exposure to PICs emitted by the tire fire. This results in an estimated lifetime cancer risk for those persons with the highest exposure of 2×10^{-4} or about 2 in 10,000. This is significantly higher than the estimate using the B(a)P unit risk number, 2 in one million.

It should be kept in mind that the risk estimates given here for both B(a)P and PICs are for those few people with the highest exposure to emissions from the tire fire. According to the model used by EPA, only 4 persons are living in this area of highest exposure (0.26 ug/m^3 of B(a)P). Exposures for other people living around the fire were less as can be seen in Figures 1 and 2 (isopleth maps) of the Attachment. In the area

west of the fire and within about 0.6 miles, the model we used predicts a population of roughly 1200 residents. Their estimated exposure ranges from about 0.023 ug/m^3 B(a)P to 0.26 ug/m^3 B(a)P. People living in Snohomish, Monroe, and Lynnwood were exposed to B(a)P levels between 0.0002 ug/m^3 and 0.002 ug/m^3. Therefore their risk is substantially less than that of the highest exposure group.

It must also be stressed that there are many assumptions and uncertainties involved in this type of risk estimate. For example, for carcinogens, EPA assumes that a linear relationship exists between exposure and cancer risk (e.g., a person who inhales one microgram of B(a)P per cubic meter of air is one-tenth as likely to get cancer as a person who inhales 10 micrograms per cubic meter). A mathematical model based upon this assumption is used to estimate the unit risk number; the model relies upon laboratory data in animals (B(a)P) or studies of workers or community exposures (PIC). Because this model is conservative, the risk numbers generated represent upper bounds of risk rather than an actual expected level of risk. The actual level of risk in terms of excess cancers is somewhere between zero and the risk value calculated here (2 in one million for B(a)P and 2 in 10,000 for PIC). Other assumptions and uncertainties are discussed below:

(1) Modeling - In Attachment A, Table 2, a comparison is made between the ambient levels of B(a)P predicted from the dispersion model and those measured (observed) by PSAPCA. The discrepancies between these two numbers are likely a result of several factors including:

° Emission estimates of B(a)P from the fire were based upon emission rates obtained from the literature not measured data from the fire

° The dispersion model that estimates the ambient levels of B(a)P at various points is limited in dealing with complex geographic and meteorological conditions as well as non-constant emissions of pollutants as was the case with the tire fire

° The number of ambient air samples analyzed by EPA were too few in number to consider them a very good representation of an average concentration over the two-month period of the fire. Additionally, these samples were analyzed more than 10 months after collection; volatilization and decomposition of substances on the filter may have occurred.

(2) Exposure

° Much of the information available on carcinogens, including development of potency numbers such as the unit risk numbers, are from laboratory or occupational studies where exposure occurred over a long time period. The use of such numbers for a two month exposure to B(a)P as occurred with the tire fire may not be appropriate.

° Exposure to B(a)P and PICs from inhalation of contaminated dust or from ingestion of contaminated soils and dusts by children has not been considered.

(3) Unit Risk Numbers

There is a even more uncertainty with the PIC unit risk number than with other unit risk numbers, in part because of the way it was derived and because B(a)P is used as a surrogate. For example, the PIC unit risk number is derived from studies of workers and communities. The types of chemicals present in these situations may be very different from those emitted from the tire fire.

Conclusion

This assessment of the long term health effects from the tire fire emissions was limited to estimating lifetime lung cancer risk for the reasons already discussed. Using conservative assumptions, this increased lifetime cancer risk may approach 2 in one million for B(a)P and 2 in 10,000 for PIC for a limited number of people (about 4) with the highest exposure to emissions from the tire fire. It should be kept in mind that there are many assumptions and uncertainties involved in this type of risk assessment (e.g., assuming that a linear relationship between exposure and cancer risk exists, estimating B(a)P emissions using literature values, using "lifetime" unit risk numbers to estimate risk from a two month exposure to the tire fire emissions). It should also be stressed that these risk estimates represent upper bounds of lung cancer risk rather than an actual expected level of risk; that is, the true risk is expected to be somewhere between zero and the risk values calculated.

ATTACHMENT

Modeling Analysis to Assess Risk
from Everett Tire Fire Emissions

The purpose of this attachment is to briefly document a modeling analysis of the air emissions from the Everett tire fire and the development of risk estimates. The modeling approach employed the Industrial Source Complex (ISC) Model to estimate concentrations, which were then input to the Human Exposure Model (HEM) to estimate risk.

Emissions estimates for benzo-a-pyrene [B(a)P] employed in the risk assessment analysis were developed based on the following information:

- 807,000 tires burned in 60 days
- 20 pounds per tire
- 18 grams of B(a)P emitted per ton of tires burned *

This yielded an average B(a)P emission rate during the fire of 0.02802 grams per second. The fire was simulated in the ISC model as a volume source with horizontal dimensions of 100 meters by 100 meters, and a vertical height of 20 meters. This accounts for initial dilution of the emissions caused by the spreading out of the fire as it progressed. It also accounts for the minimal rise of the plume during most of the two-month period. The source was located at a latitude of 47° 57' 56" north, and a longitude of 122° 11' 30" west.

Meteorological data was supplied by the Puget Sound Air Pollution Control Agency (PSAPCA). The data consisted of joint frequency distributions of wind speed, wind direction, and stability class for the two-month period from September 24 to November 23, 1984. Two distributions were developed using the wind data from PSAPCA's monitoring stations at the Medical-Dental Building on Colby Avenue in Everett, and at North 98th Street and Stone Way in North Seattle. Stability classes were developed from concurrent cloud cover and ceiling height observations at Seattle-Tacoma Airport. After preliminary model runs were completed, it became evident that the Everett wind data yielded higher modeled concentrations than the North Seattle data. Furthermore, owing to the close proximity of the Everett station to the fire location, the Everett wind data are judged to be more representative of the conditions which affected the fire than the North Seattle data. Thus, all subsequent modeling analyses utilized the Everett meteorological data set.

Other meteorological data input to the ISC model are documented in Table 1. The values are listed as a function of stability class. The temperatures and mixing heights are based on historical climatological data for the Seattle area. The vertical potential temperature gradients and the vertical wind profile exponents are normal default values.

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* "Atmospheric Emissions from Open Burning," Richard Gerstle and Douglas Kemnitz, Journal of the Air Pollution Control Association, Volume 7, Number 5, May 1967, page 324.

Concentrations were estimated using the rural mode of the long-term version of the ISC model (EPA-450/4-79-030). ISC is a standard gaussian model intended for use in flat or gently rolling terrain. Deviations in plume trajectories resulting from wind flows which are altered by complex terrain are not simulated by ISC. Elevated stable plume impact on high terrain is also not modeled by ISC. However, because of the minimal plume rise during most of the fire, stable plume impact should not be a significant factor in this analysis. ISC does not, as all gaussian models do not, simulate very low wind speed conditions well. Light and variable winds were reported about 4% of the time during the fire. In spite of these limitations, the ISC model is judged to be adequate for this analysis.

Receptors in the modeling analysis were set in a polar grid with the fire at the center of the grid. Sixteen grid radials were spaced at azimuths of 22.5° around a 360° circle. Concentric rings of receptors were located at ranges from the fire in kilometers of 0.5, 1.0, 1.5, 2, 3, 4, 5, 7, 9, 12, 15, 20, 25, 30, 40, and 50. This grid layout yields 256 receptors.

ISC was used to calculate average concentrations of B(a)P at all receptor locations. The results are displayed in Figures 1 and 2. Figure 1 contains the predicted spatial distribution of B(a)P within a few kilometers of the fire location, while the predicted concentrations over the entire receptor grid are shown in Figure 2. These figures show how concentration decreases significantly with increasing distance from the fire. For example, the highest concentration estimate (0.26 micrograms per cubic meter) was one-half kilometer to the northwest of the fire, near the I-5 freeway. Further into Everett near the intersection of Hewitt and Broadway, the average concentration was only about one-fifth of the maximum. And, near Oak Harbor on Whidbey Island, the average concentration estimate dropped by about a factor of 300 from the maximum. The concentration drops even more rapidly in other directions from the fire.

Measured ambient concentration data collected by PSAPCA at their Everett and North Seattle monitoring stations were obtained. The measured values were averaged over the duration of the fire for comparison with the model estimates. The model estimated concentrations were interpolated from the grid receptors to the monitoring locations so that a rough comparison of predicted and observed concentrations could be made. The results of this comparison are listed in Table 2.

There are several factors which suggest that this comparison is crude at best, and may in part explain some of the discrepancies between the predicted and observed concentrations. While the emissions estimates are based on the best information available, they must be considered very approximate. The plume from the Everett tire fire was not sampled, so that emission factors had to be obtained from the literature. ISC assumes that the fire emissions are constant, while in reality the fire emissions were obviously not constant with time. No background concentration was subtracted from the measurements, so that the measured values include contributions from sources other than the tire fire. No measurements of ambient concentrations were available for November. The numbers of 24-hour averaged samples for B(a)P at the Everett and North Seattle monitors are really too small to

consider them a very good representation of an average concentration over the two-month period of the fire. Finally, the limited ability of the ISC model to handle complex terrain and low wind speeds is also a factor in the comparison.

It is not possible to draw any firm conclusions from the comparison. Statistical significance of the differences (or similarities) between the measurements and the model estimates can not be established. From this limited evaluation it appears that the modeled concentration estimates are probably good enough for order-of-magnitude risk estimates.

The output concentration estimates from the ISC model were input to the HEM developed by Systems Applications, Inc. under contract to EPA. A draft user's manual for HEM (October 1985) was obtained from the Pollutant Assessment Branch at the EPA Office of Air Quality Planning and Standards. HEM uses the ISC concentration estimates and the population data from the 1980 census to estimate exposures. Risk estimates were developed with HEM using two different unit risk factors: the B(a)P unit risk factor of 0.0033 per microgram per cubic meter, and the unit risk factor for products of incomplete combustion (PIC) of 0.42 per microgram per cubic meter. The HEM assumes a lifetime (70-year) exposure. Therefore, the risk estimates were adjusted for the shorter two-month exposure resulting from the fire. This amounted to dividing the lifetime values by 420, the number of two-month periods in 70 years.

The results from the HEM are listed in Table 3. The maximum individual risk estimates due to emissions from the fire are for people who live very close to the fire location. These analyses extended to a radial distance of 50 kilometers from the fire. The total number of people within this area is approximately 1.23 million. The minimum risk is the lowest risk value to which the entire population was exposed.

Table 1

Meteorological Data Input to the ISC Model

Stability Class	Temp. (deg K)	Mixing Height (meters)	Potential Temp. Grad. (deg K / m)	Wind Profile Exponent
A	286	950	0.0	0.10
B	285	850	0.0	0.15
C	284	750	0.0	0.20
D	282	750	0.0	0.25
E	280	10000	0.020	0.30
F	279	10000	0.035	0.30

Table 2

Comparison of Estimated and Measured B(a)P Concentrations

Monitoring Station	ISC Estimate (micrograms per cubic meter)	Average Measured Concentration (micrograms per cubic meter)	Number of 24-Hour Samples
Everett	0.0484	0.0142	8
North Seattle	0.000276	0.0032	2

Table 3

Risk Estimates for B(a)P Emissions from the Everett Tire Fire Calculated by the Human Exposure Model

Unit Risk Factor Employed	0.0033 [for B(a)P]	0.42 [for PIC]
Maximum Risk to an Individual as a Result of Exposure	2.1×10^{-6}	2.4×10^{-4}
Number of People at Maximum Risk	4	4
Minimum Risk Level	3.5×10^{-10}	4.4×10^{-8}

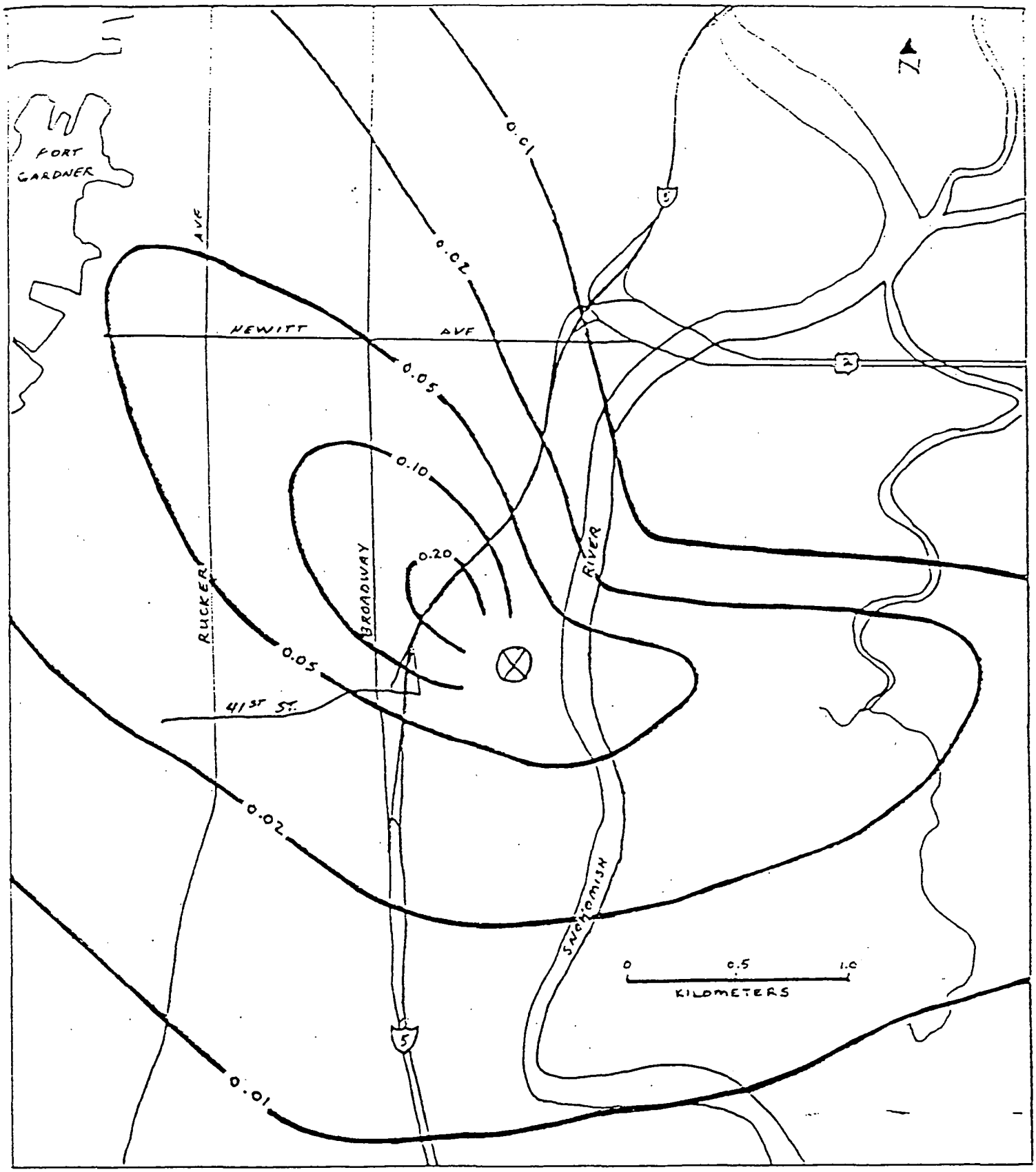

Figure 1. This map shows the spatial distribution of predicted concentrations within a few kilometers of the fire location at ⊗. The concentrations are in units of micrograms of B(a)P per cubic meter of air averaged over the two-month period of the fire.

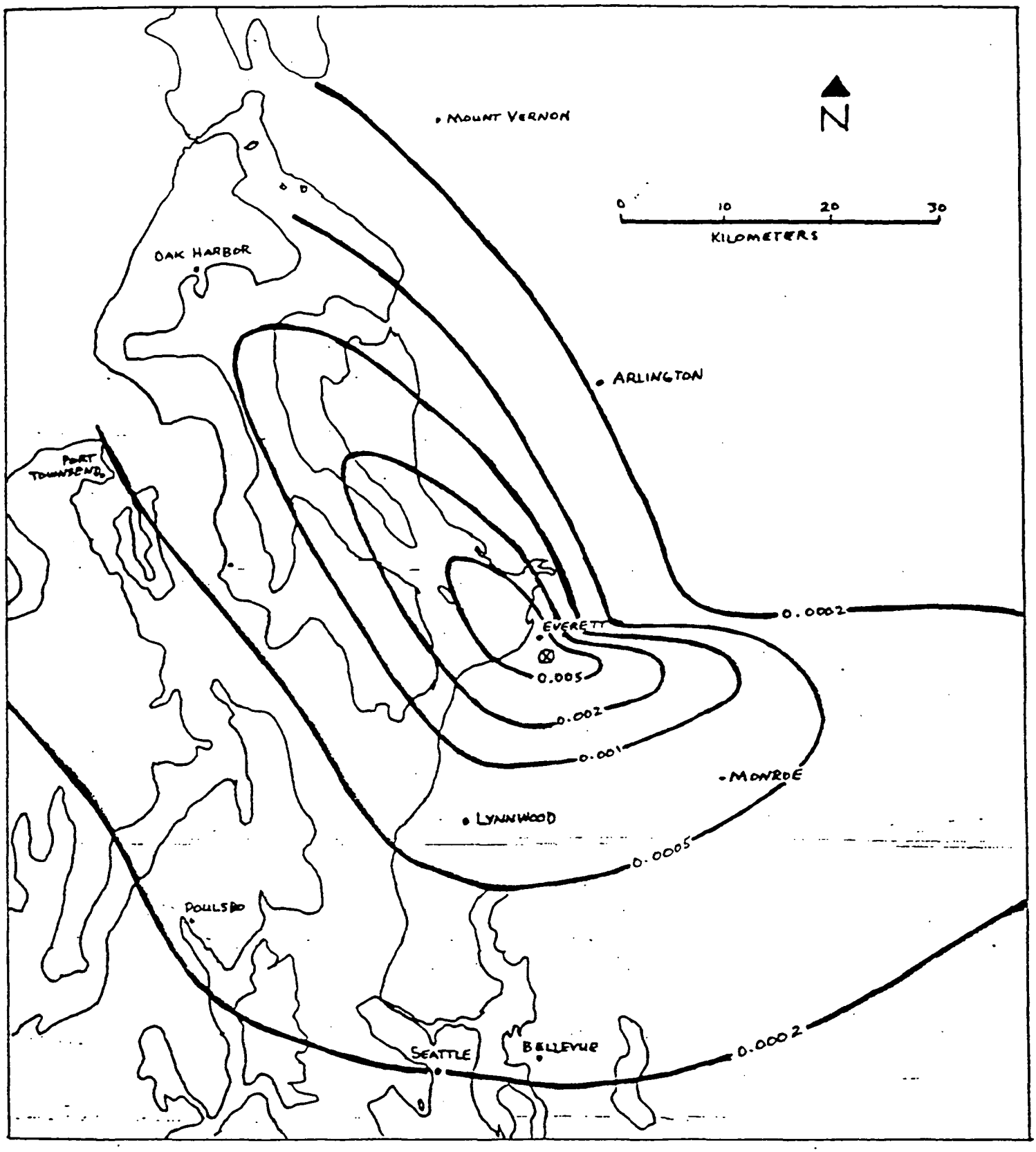

Figure 2. This map shows the spatial distribution of predicted concentrations over the entire modeling grid, within 50 kilometers of the fire location at ⊗. The concentrations are in units of micrograms of B(a)P per cubic meter of air averaged over the two-month period of the fire.