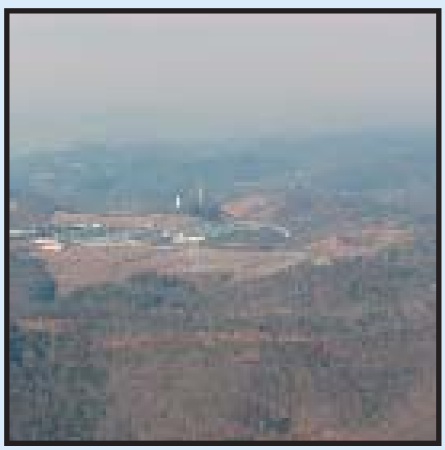


Kanawha Valley "Blue Haze" Incident of January 25, 2008


West Virginia Department of Environmental Protection • Division of Air Quality

May 2008

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“Blue Haze” Incident
of
January 25, 2008

West Virginia Department of Environmental Protection
Division of Air Quality
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May 2008

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1. Looking southwest from above the Spring Hill Cemetery. Downtown Charleston in left-center of photograph. 3:36 p.m. January 25

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3. Looking north from above Institute. 3:41 p.m. January 25

4. Looking north from above Institute. Cross Lanes Wal-Mart in foreground. 3:42 p.m. January 25

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6. Looking southeast from above Nitro. Bayer CropScience facility, in Institute, in foreground. 3:42 p.m. January 25

Note: All photographs taken January 25, 2008, by an engineer-photographer in the Division of Air Quality (DAQ) of the West Virginia Department Environmental Protection, during the first of two aerial surveys by DAQ using a state helicopter.

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EXECUTIVE SUMMARY

On Friday, January 25, 2008, a meteorological condition called a temperature inversion occurred around midday that rapidly triggered an air-pollution episode affecting the Kanawha Valley in central West Virginia, from Charleston to the Winfield area, which is approximately 15 miles downriver. The public complained of a blue haze and a chlorine or bleach-like odor.

During this incident, which has become known as the blue-haze incident, the inversion trapped pollutants in the Kanawha Valley, including $PM_{2.5}$ (particulate matter less than or equal to 2.5 microns in diameter) which exceeded the federal health-based 24 hour standard at the air monitoring site in South Charleston. That prolonged weather event caused ambient air concentrations of pollutants to rise. But urban conditions also appear to have induced a phenomenon called an urban haze-hood, which further aggravated the impact of the inversion.

Along with local and other state agencies, the West Virginia Department of Environmental Protection (DEP), through its Division of Air Quality (DAQ) and Division of Homeland Security and Emergency Response, responded promptly to this episode. As requested, DEP provided investigatory and advisory services, including technical advice.

This report presents information on DEP's response on January 25, accomplishing two other objectives. First, it establishes the regulatory and meteorological conditions and situations prior to and following the incident. Second, it provides the department's assessment of what it believes happened January 25 and why, as well as any immediate air-quality impact or impacts that may have occurred.

ES-1. Haze

While DEP acknowledges that some unknowns still exist to determine what caused the blue-haze incident, DEP believes a preponderance of evidence clearly shows the John Amos Power Plant (Amos), which is owned by American Electric Power Company, in

Winfield, was a major contributor to the haze problem, once the inversion occurred. DEP bases this conclusion on information discussed in this report, particularly Chapter 3 Sections 3.1.1 and 3.2 through 3.6, as well as information in Chap. 2 and DAQ's to-date observations and investigations. Photograph ES-1, taken in mid-afternoon January 25 by a DAQ engineer from a helicopter during an aerial reconnaissance of the Kanawha Valley, shows the impact of the inversion on the Amos emissions.

Photograph ES-1. Looking north from above Institute. Note the Cross Lanes Wal-Mart in the foreground. Note also: The active boiler exhaust stacks—the most slender ones of the taller stacks shown—are approximately 900 feet tall. That would indicate that the inversion layer above the plant was approximately 2,500-3,000 feet above the Kanawha Valley floor.

- In the Kanawha Valley, the Amos plant is the largest single emitter of $PM_{2.5}$, which is particulate matter with an aerodynamic diameter of 2.5 microns (approximately 1/10,000th of an inch) or less, and which is substantially smaller than the typical diameter of human hair (70-100 microns). Particles at this size contribute to visibility impairment, through absorption and scattering of visible light.

- Amos is also the Kanawha Valley's largest single emitter of sulfur dioxide or SO_2; and nitrogen oxides, or NO_X. Both chemical compounds, when atmospherically changed to sulfates and nitrates, respectively, contribute to haze because of their transformation into $PM_{2.5}$.

- Amos is the Kanawha Valley's largest single emitter of both sulfuric acid, H_2SO_4, and hydrochloric acid, HCl, both which may be transformed into aerosols. These particles, which are classified as $PM_{2.5}$, can reflect or scatter light in the atmosphere, creating a blue-gray haze.

- Analysis of $PM_{2.5}$ filters from the South Charleston site indicates that both sulfates and elemental sulfur were significant contributors to the 24 hour $PM_{2.5}$ NAAQS exceedance at that site. Both are strongly associated with coal-fired combustion like that at Amos.

Based on the following, DEP also concludes that the thermal inversion created fumigating conditions at and in the vicinity of Amos that created and then prolonged the blue-haze incident. Fumigating conditions are caused when pollutants from the stack concentrate near ground level.

- A time-lapse video taken by a local television station's camera mounted atop a microwave tower in downtown Charleston captured the initial fumigation and the rapid change in atmospheric conditions.

- The video showed a distinct haze moving steadily upriver from the Poca-Winfield area, where the Amos plant is located, obscuring more and more of the background as it moved.

- While the sulfuric acid emitted from the Amos plant as currently configured is vapor, which has no optical properties, DAQ believes that on January 25 atmospheric conditions, at some distance from the plant, transformed the vapor into an aerosol, which refracts or reflects the blue part of the visible-light spectrum.

The DAQ notes that regardless of the impact of the combined categories of plant emissions—and given that all other operating stationary facilities' and mobile sources' emissions were trapped in the Kanawha Valley until the inversion ended—the meteorological conditions that created the inversion likely would have led to some level of increased haziness in the Kanawha Valley, even if the Amos plant had not been operating on January 25.

DAQ also notes that in addition to the major stationary facilities operating January 25 in the Kanawha Valley, minor industrial, commercial, institutional and residential sources also operated.

ES-2. Odor

Regarding the complaint of chlorine- or bleach-like odors, while the source or sources of these odors remain unknown, potential sources south and west of downtown Charleston exist that could have contributed to that odor on that day. In addition to Amos, these include Bayer CropScience in Institute, and Clearon Corporation and Dow/Union Carbide Corporation, South Charleston.

However, DEP acknowledges and emphasizes the following about these stationary facilities, as well as all other stationary and mobile sources that were operating January 25 in the affected part of the Kanawha Valley:

- None of the facilities mentioned, or any other stationary source in the Kanawha Valley, reported any malfunction on January 25.

- None of the facilities mentioned, or any other stationary source in the Kanawha Valley, reported on January 25 that any seals or gaskets on pumps, valves or any other such equipment ruptured or failed, causing an accidental release of any chemical—particularly one with a chlorine or chlorine-like odor.

- Through ground and aerial surveillance on January 25, DEP observed no obvious and/or visible leaks of chemicals from any stationary facility in the Kanawha Valley.

- Through direct telephone surveys of major sources that could have contributed to any odor complaint like those received at DEP on January 25, DAQ learned of no accidental spill or release of chlorine, any other chemicals with a chlorine or chlorine-like odor, or any other chemicals from those facilities.

- DEP remains unaware of any reports of accidental spills or releases of chlorine, chemicals with a chlorine or chlorine-like odor, or other chemicals from mobile sources, such as trailer trucks, barges, rail cars or tankers, on January 25.

- Minor industrial, commercial, institutional and residential sources also operated in the Kanawha Valley on January 25.

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LIST OF ACRONYMS, ABBREVIATIONS AND SYMBOLS

%	percent
&	and
AEP	American Electric Power Company
C&E	Compliance & Enforcement
Chap.	chapter
Cl_2	chlorine
DAQ	Division of Air Quality
DEP	West Virginia Department of Environmental Protection
Emergency Response	Division of Homeland Security and Emergency Response
EPA	U.S. Environmental Protection Agency
ESP	electrostatic precipitator
EST	Eastern Standard Time
FGD	flue-gas desulfurization
Fig.	figure
H_2O	water
H_2SO_4	sulfuric acid
HCl	hydrochloric acid
lb/day	pounds per day
lb/hr	pounds per hour
mph	miles per hour
MW	megawatts; or 1,000,000 watts
NO_X	nitrogen oxides
NWS	National Weather Service
O_2	oxygen
OES	Office of Emergency Services, now WVDHSEM
^oF	degrees Fahrenheit
PM	particulate matter
PM_{10}	PM with an aerodynamic diameter of less than or equal to approximately 4/10,000th of an inch
$PM_{2.5}$	PM with an aerodynamic diameter of less than or equal to approximately 1/10,000th of an inch
ppm	parts per million
S	sulfur
SCR	selective catalytic reduction
SO_2	sulfur dioxide
SO_3	sulfur trioxide
VOCs	volatile organic compounds
W.Va.	West Virginia
WVDHSEM	West Virginia Division of Homeland Security and Emergency Response
$\mu g/M^3$ or ug/M^3	microgram per cubic meter of air
$\mu g/m^3$ or ug/m^3	microgram per cubic meter of air

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CHAPTER 1
INTRODUCTION

On Friday, January 25, 2008, a meteorological condition called a temperature inversion rapidly triggered an air pollution episode that affected the Kanawha River Valley from Charleston to the Winfield area, approximately 15 miles downriver of Charleston, W.Va. During this episode, the public complained of a blue haze and, most often, of a chlorine or bleach-like odor.

The West Virginia Department of Environmental Protection (DEP) responded promptly to this episode, which has become known as the blue-haze incident. DEP provided investigatory and advisory services and, as appropriate, technical advice. Involved principally were the DEP's Division of Air Quality (DAQ) and DEP Executive Office's Homeland Security and Emergency Response (Emergency Response).

Some examples of the agencies' responses include:

- Almost immediately after receiving the first complaints, DAQ engineers in the division's Compliance & Enforcement Section (C&E) began calling companies to find if abnormal operating conditions occurred, or if accidental releases or spills of chemicals happened.

- DAQ quickly deployed to the field by both ground and air transport to attempt to find the source or sources of the haze and the odor.

- The chief of DEP's Emergency Response began coordinating with the Director of the West Virginia Division of Homeland Security and Emergency Management (WVDHSEM), who coordinated state agencies' response, as well as communications with local Kanawha county responders.

- The DAQ director (director) and members of his staff spoke with print and broadcast news media, when requested, to get factual and timely information to the public.

- DAQ researched potential causes and had several conversations with representatives of American Electric Power Company regarding its John Amos Plant. These conversations were followed up by two meetings, one by conference call and the other at DEP headquarters.

This report presents information on DEP’s response, sets the background for the incident and details what the department believes occurred January 25.

CHAPTER 2
BACKGROUND

To establish the background for the agency's response in the first 12 hours of the incident and the follow-up thereafter, this chapter presents various facets of the background of the day. Primarily, these include regulatory and meteorological events and perspectives.

2.1. Regulatory

2.1.1 Prior to the First Complaint

On January 25, 2008, in the 35-or-so-mile portion of the Kanawha River Valley from Poca, which is west or downriver of Charleston, to Belle, which is east or upriver of Charleston, two general types of air pollution sources operated: stationary and mobile.

Stationary sources included, for example, general manufacturing; heavy or light industry; chemical-processing/-manufacturing facilities; power plants, such as the AEP-owned Amos plant in Winfield; industrial, commercial and institutional boilers; industrial or commercial liquid-storage vessels; incinerators; natural-gas compressor stations; restaurants; gasoline stations; a landfill; wood- and/or coal-burning stoves; natural-gas and wood fireplaces; etc.

Mobile sources included trains and railway tank cars; river barges and/or vessels on those barges; gasoline- and diesel-powered passenger vehicles; light and heavy-duty gasoline- and diesel-powered trucks, including tankers and buses; construction equipment; motorcycles; aircraft; recreational vehicles; etc.

Regarding air pollution-related complaints from citizens about operations of industries in the Kanawha River Valley, according to the DAQ's assistant director for Compliance & Enforcement (assistant director), there was nothing unusual reported that day until the blue-haze incident unfolded in the early afternoon.

DAQ is aware of no reports of malfunction at any major stationary source of air pollution; nor of any accidental release or spill of chemicals from those sources, as well as trains or railway cars, barges or vessels on those barges, or highway tanker trucks.

2.1.2. The Complaints

Shortly after 1 p.m. on January 25, some DEP staff out in the field or at locations other than DEP headquarters in Kanawha City began to contact headquarters, to either notify DEP headquarters of the situation or learn more about it.

Simultaneously, citizens began to lodge complaints with the DEP about haze and/or odor. Calls came to the receptionists' desks, the Environmental Advocate who is part of the executive office of the cabinet secretary of the DEP, the DEP's Division of Homeland Security and Emergency Response office on the Elk River and individuals within DAQ. Photograph 2-1, taken at approximately 3:36 p.m. by a DAQ engineer in a helicopter, shows the haze. Note, though, that the observer's perspective has the sun to front and side, a position that would influence—and potentially alter or worsen—the perceived color of the haze.

Despite their concern, many callers would not leave a message with the receptionists. Nor did some apparently leave messages on the voicemail of DEP staff to which the complainants' calls were forwarded. Some callers were former DEP staff or relatives of current DEP staff. Some callers also contacted the agency more than once.

Not all complaints were alike, as the following examples indicate:

- Some callers spoke about a blue haze having a chlorine odor.
- Two callers described the odor as a "horrible smell."
- A complainant calling from the Interstate 64-Interstate 77 junction, just north of downtown Charleston, characterized the haze and odor, respectively, as smoke and sulfur and formaldehyde.

- Some callers from the South Charleston area complained of their eyes “burning” because of the haze.
- Two callers from Institute mentioned a “strong chlorine odor.”

Photograph 2-1. Looking southwest at 3:36 p.m., January 25, just after the state helicopter carrying DEP staff, on their first aerial reconnaissance, had taken off from Yeager Airport and was beginning its turn downriver.

Though not a complainant, a DAQ employee who’d been to the division’s laboratory at the Guthrie Agricultural Center, which is a few miles north of the valley proper and Charleston, saw the haze as soon as she entered the valley from the north at about 3:30 p.m.

- She recalled thinking there had been a forest fire. As she drove further west into Dunbar, she noted that the haze appeared to get denser.

- In Dunbar, where she stopped briefly, she noted an acrid smell in the air, which she described as chlorine- or bleach-like.

- Arriving between 4 and 4:30 p.m. at her home in the Spring Hill section of South Charleston, she could not see into the valley. Normally, on a clear day, she said she could see up and down the valley because of her home's elevation above the river.

- Unlike what she smelled earlier in Dunbar, she noticed no atmospheric odor at her home's location.

Also, just a few minutes past 4 p.m., another DAQ staff member, who left the agency's Kanawha City headquarters only minutes earlier, reported that when she arrived at the Southside Bridge, while traveling west on MacCorkle Ave., she noticed a very strong blue haze. She also noted that while the windows of her vehicle were not lowered, she could smell a definite odor insider her vehicle that reminded her of the odor associated with a coal stove or furnace.

As the incident unfolded, receptionists recalled that there had been a "flood" of calls from just after 1 p.m. until about 5:30 p.m., when the calls began to taper off. The receptionists also noted that shortly after the calls began coming into the agency, they began apprising callers that the DEP, particularly DAQ, was aware of the situation, and that it was being investigated.

2.1.3. The Incident Response Initiated

According to the chief of Emergency Response, this incident was characterized as a local emergency. However, the national model for multi-agency response, the Incident Command System, was the framework applied. Using it, the Kanawha County Emergency Services established the overall incident command center at its 911 Center, where emergency calls are received from the public, located on U.S. Route 19 South, also known as Corridor G.

Through its chief of Emergency Response, the department coordinated its overall efforts through the WVDHSEM. That division, which continues to be called by many as the Office of Emergency Services, or OES, established its command center at its offices in the Capitol Complex.

DEP's aggressive investigation and response, which began after the first telephone calls were received at its headquarters, continued for approximately 12 hours, until it appeared that the incident had essentially ended.

In those initial 12 hours, DEP response activities included:

- Almost immediately after learning of the first complaints, at the direction of the assistant director and the supervisor of DAQ's Compliance & Enforcement Section (supervisor), DAQ engineers began calling companies in the valley, including AEP's Amos power plant, to determine if there had been an accidental spill or release of chlorine, chemicals with a chlorine-like odor, or other chemicals from those facilities.

- Within 30-45 minutes of the first call to DAQ, the division sent a field engineer by car to investigate.

- Within approximately two hours of the first complaint, the chief of Emergency Response, the supervisor and a C&E engineer were airborne in a helicopter to investigate.

- By 6 p.m., the chief of Emergency Response and supervisor had made two aerial reconnaissance flights over the valley, particularly in the vicinity of the Amos power plant.

- The DAQ director was interviewed by local news media, which began calling in early afternoon. One story was posted online following an interview.

- By 9 p.m., the last of the DAQ employees at headquarters involved in the response, including those who had been in the field, had left for their homes.

- At approximately 12:30 or 1 a.m. January 26, when it was evident that the day's response activities were completed or nearly complete, the chief of Emergency Response left the state responders' command center and went home.

2.1.4. The Immediate Follow-up

DEP's response resumed, almost exclusively through DAQ, just a few hours later Saturday morning, and then continued through the next four weeks. The most intense follow-up activity occurred within the first few days, and then two weeks following the incident.

Early Saturday, January 26, the assistant director for Air Monitoring/Laboratory electronically retrieved and then transmitted the data shown in Table 2-1 to the DAQ director. The data came from an ambient-air-quality-monitoring site atop the Baptist Temple, in downtown Charleston. Among other functions, the site tracks particulate matter, or PM, and sulfur dioxide, SO_2, in the immediate Kanawha River Valley. The data encompassed the interval from approximately 1 p.m. January 24 to midnight January 25. As exhibited, the highest values appeared to occur from 3 or 4 p.m. to about 9 or 10 p.m. January 25. The director subsequently used this data in a videotaped interview conducted and aired Saturday, January 26 by a Charleston television station news crew. In the interview, the DAQ director indicated that the Baptist Temple data showed there was no violation of any National Ambient Air Quality Standard during the incident. He did note that there had been what is called a spike in—or elevation of—the PM and SO_2 values.

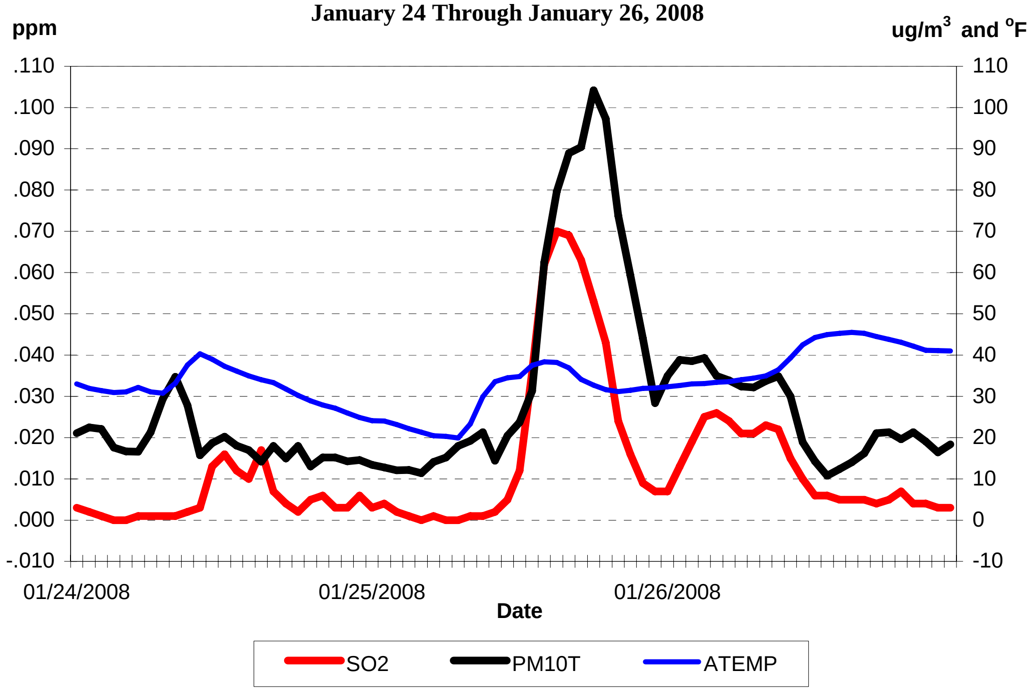
Table 2-1.
Ambient Air Quality Data for Baptist Temple Site, Downtown Charleston, W.Va.
January 25, 2008

Date	Hour	STEMP	ATEMP	SO2B	TFILT	PM10T	SO2
1/25/2008	0	71.9	24.1	0.005	51	13.4	0.003
1/25/2008	1	71.7	24	0.005	51	12.8	0.004
1/25/2008	2	71.6	23.2	0.003	51	12.1	0.002
1/25/2008	3	71.5	22.2	0.003	51	12.2	0.001
1/25/2008	4	71	21.3	0.003	52	11.4	0.001
1/25/2008	5	70.8	20.5	0.003	52	14.1	0.001
1/25/2008	6	70.5	20.3	0.002	52	15.2	0.001
1/25/2008	7	70.7	19.9	0.002	52	18	0.001
1/25/2008	8	71.5	23.3	0.003	51	19.2	0.001
1/25/2008	9	72.5	29.9	0.003	50	21.3	0.001
1/25/2008	10	72.9	33.6	0.004	50	14.4	0.002
1/25/2008	11	73.2	34.5	0.006	50	20.5	0.005
1/25/2008	12	73.1	34.8	0.013	50	23.7	0.012
1/25/2008	13	74	37.5	0.037	49	31.3	0.036
1/25/2008	14	75.6	38.4	0.063	49	62.5	0.062
1/25/2008	15	76.7	38.2	0.071	49	79.6	0.07
1/25/2008	16	77.5	36.9	0.069	49	88.9	0.069
1/25/2008	17	76.7	34.1	0.064	50	90.4	0.063
1/25/2008	18	75.8	32.7	0.054	50	104.2	0.053
1/25/2008	19	75.6	31.6	0.044	51	97.3	0.043
1/25/2008	20	75.3	31.2	0.026	51	73.8	0.024
1/25/2008	21	75	31.5	0.017	51	59.3	0.016
1/25/2008	22	74.7	31.9	0.011	52	44	0.009
1/25/2008	23	74.4	32	0.009	52	28.4	0.007

Notes:
STEMP = sample temperature, degrees Fahrenheit (^oF)
ATEMP = air temperature at the monitoring site, ^oF
SO2B = backup SO_2 concentration, μg/M^3
TFILT = filter temperature, ^oF
PM10T = PM_{10} concentration, μg/M^3
SO2 = primary SO_2 concentration to be used, μg/M_3
Hour denotes the beginning of the hour, using universal or military time. For example, 0 = 12:01-1 a.m.

Fig. 2-1 graphically depicts these data for January 25, as well as some data for January 24 and 26.

Fig. 2-1.
PM_{10} and SO_2 Readings at Charleston/Baptist Temple
January 24 Through January 26, 2008



Notes:
ATEMP equals air temperature at the monitoring site; PM10T equals total PM_{10}.
ppm equals parts per million
ug/m^3 equals micrograms per cubic meter (one microgram equals approximately 1/10,000,000th of an ounce; or 0.0000000353 ounces)
°F equals degrees Fahrenheit
The National Ambient Air Quality Standard (NAAQS) for PM_{10}, for a specified 24-hour period, is 150 μg/m^3.
The NAAQS for SO_2, for a specified three-hour period, is 0.5 ppm.
The NAAQS for SO_2, for a specified 24-hour period, is 0.14 ppm.
The 24-hour NAAQS for SO_2 is the primary standard.

- The pollutant with the highest peak on Fig. 2-1 is PM_{10} or particulate matter having an aerodynamic diameter of 10 microns or less (approximately 0.000394 inches or less; or 4/10,000th of an inch), which is substantially smaller than typical human hair (70-100 microns). Fig. 2-2 also shows the comparison of PM_{10} with $PM_{2.5}$, which is particulate matter having an aerodynamic diameter of less than or equal to approximately 1/10,000th of an inch.

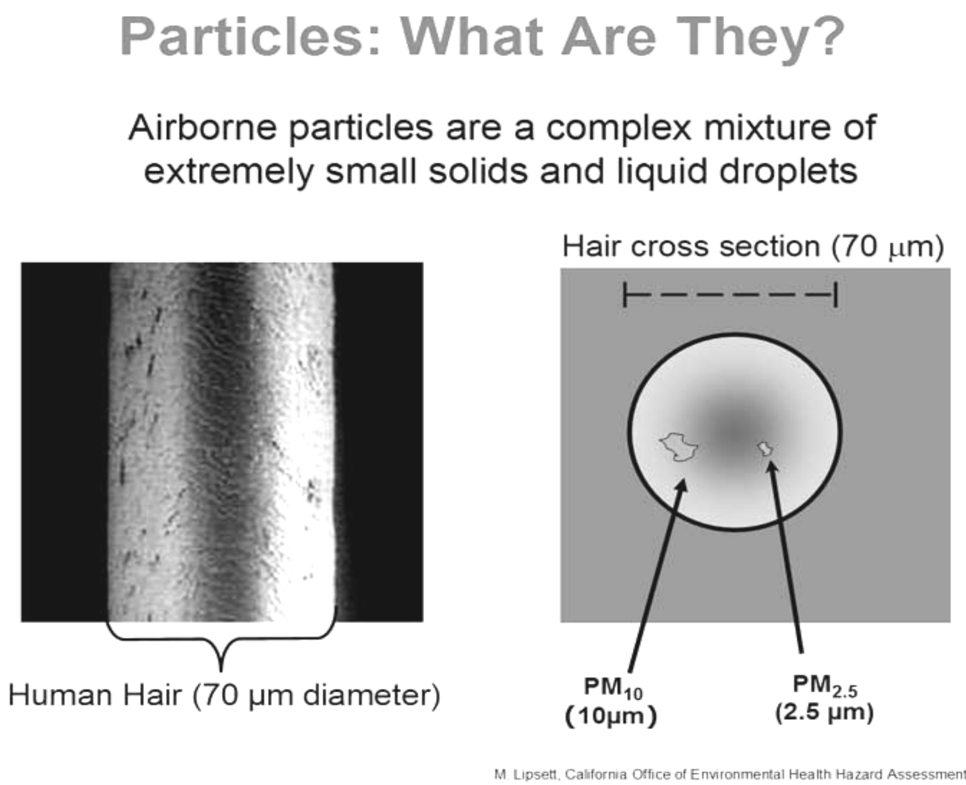
- The pollutant with the smaller increase is SO_2.

- Both are combustion-related pollutants, especially SO_2.

- The $PM_{2.5}$ monitors in the Kanawha Valley were running on a regularly scheduled sample day on January 25. Each monitor collects a sample from midnight to midnight once every third day. The samples, collected on a filter, are retrieved and sent to the laboratory for processing. Because of processing and quality assurance requirements, that data was not available until several days after the January 25 incident. Elevated $PM_{2.5}$ levels of 34.1 $\mu g/m^3$ were monitored at the Baptist Temple monitoring site in downtown Charleston while levels at the South Charleston site reached 49.7 $\mu g/m^3$, which exceeds the EPA health-based NAAQS.

Fig. 2-2.

Comparison of Diameters of Human Hair, PM_{10} and $PM_{2.5}$



Notes: 1 µm = 1 micrometer = 1 millionth of a meter = approximately 4/ 100,000th of an inch.
Approximately 30 $PM_{2.5}$ particles could fit along the diameter of the typical human hair.

Besides interactions with the news media Saturday morning, January 26, other follow-up activities by the DAQ director and his division included:

- Participating with the director of the Kanawha County Emergency Services in a briefing at the 911 Center for two local television stations on Monday, January 28;

- providing supplemental information and participating in telephone interviews with news media, particularly a local newspaper over the next three to four weeks;

- continuing to gather and/or analyze data, or ambient-air-quality filters or samples, and seeking further analysis from other laboratories;

- gathering and analyzing specific emissions-related data from AEP regarding its Amos power plant;

- and continuing its response through analysis of data or initiating analyses of ambient-air-monitoring filters.

2.2. Meteorological

From data reported by the National Weather Service (NWS) and recorded at Yeager Airport (Yeager), there appeared to be nothing unusual, other than an extended period of calm winds. This section presents some data that extend into late morning January 26, to indicate the prevalence of certain conditions that arose on January 25; specifically, wind speed and direction, as well as visibility.

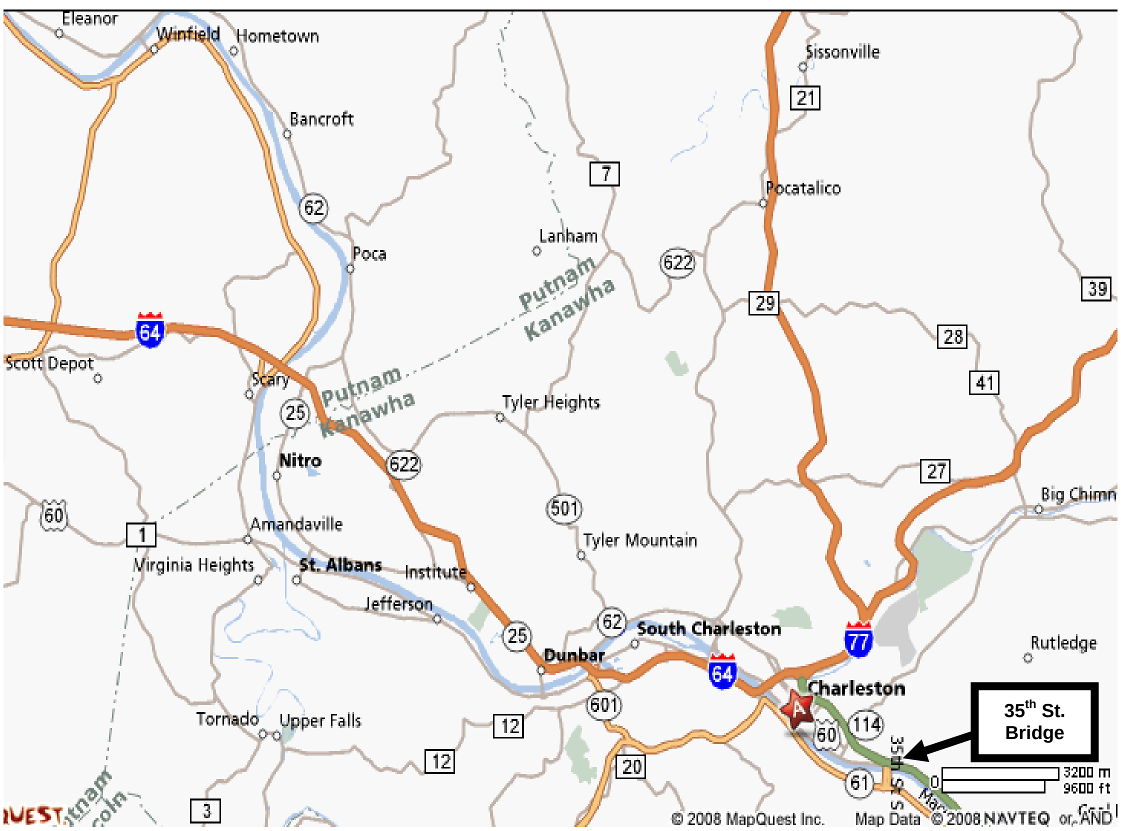
Meteorologically, after approximately 4 a.m. on January 25, winds measured at Yeager became calm, which means they had no or essentially no measurable direction or speed. Partly cloudy skies of the morning gave way to clear skies of early afternoon, according to observations made at Yeager.

At noon or thereabouts, the governor and the WVDHSEM director were in a helicopter returning from a morning trip to Logan. The director recalled a conversation in the aircraft about how beautiful the day was and how clear skies were. He noted no haze. He also said he could see the steam plumes rising from the downriver Amos power plant.

2.2.1. Inversion Onset

For some period between noon and approximately 1 p.m., although no one knows exactly how long, skies remained clear.

But sometime during that period, atmospheric conditions changed rapidly and radically. In an approximately 35-mile section of the valley—particularly west of the 35th Street Bridge to just south of and across the river from Poca—a meteorological event called an inversion apparently occurred very swiftly. Map 2-1 shows the affected area of the valley.



Map 2-1. Map of affected portion of Kanawha River Valley. Towns or cities in the actual river valley include, among others, Charleston, South Charleston, Dunbar, Institute, St. Albans, Nitro, Poca and Winfield.

During an inversion, normal temperature patterns seen in the lower atmosphere reverse. Warm air is lighter than cool air so, typically, hot air from the earth's surface rises and then cools as it ascends. While inversions may occur in any season, in winter a temperature inversion may occur when a layer of warmer air aloft traps a layer of colder air close to the ground surface causing air stagnation.

A NWS meteorologist from Charleston who had been on duty the night of January 25 suggested that what occurred over the valley was a very strong or thick inversion that he estimated was 1,500-2,000 feet above the valley. Aerial photographs taken January 25 by DEP staff suggest that the inversion layer may have been as high as 2,500-3,000 feet above the valley, at the Amos plant.

Regarding the visible haze in the valley, the meteorologist indicated it resulted from the strong inversion combining with low wind speeds. But he did not characterize the meteorological event as being necessarily unusual.

However, two other phenomena appeared to have occurred that further aggravated the impact of the inversion. The first was the urban-heat-island, which occurs when air is heated by the release of heat retained in concrete, metal and other materials; or from surfaces such as roofs of homes and buildings. It is also generated by residential, commercial, institutional and industrial activities and heating/cooling systems.

The second phenomenon that aggravated the impact of the inversion was the urban haze-hood or dome. As polluted air moves upward over the city into the warm-cold-air interface, the air pollutant-containing urban-air mass spreads laterally, cools and then sinks at the edge of the urban area. In doing so, it creates what may be called a haze hood or dome. Cooler air from the edges of the urban air then is drawn back into the center of the urban area to replace the air that has risen. That circulation pattern repeats until a strong wind comes that breaks up the pollution-formed ceiling and, thus, the circulation pattern.

A meteorologist from the U.S. Environmental Protection Agency's Region III office in Philadelphia later suggested this phenomenon occurred.

Regardless of exact classification of phenomena, the combination of meteorological circumstances that occurred January 25, including potential cold-air drainage down the Elk River Valley into the Kanawha River Valley, led to the valley figuratively and rapidly transforming into a large, essentially closed, container into which stationary-source and mobile-source pollutants continuously poured for hours. With little or no winds, those air pollutants were trapped beneath this inversion. Because there was no driving force or ability for contaminants to be dispersed vertically through and above the inversion layer, the pollutants' ambient concentrations increased.

A time-lapse video taken by a camera mounted atop a microwave tower in downtown Charleston visually captured the rapid change in atmospheric conditions. The camera's perspective was looking downriver, toward the chemical complexes of South Charleston and Institute, as well as the Amos plant a few miles further downriver. The video showed a bluish haze moving steadily upriver from the Poca-Winfield area, obscuring visibility.

The inversion or urban haze-hood conditions continued through the rest of the day and into the morning of January 26.

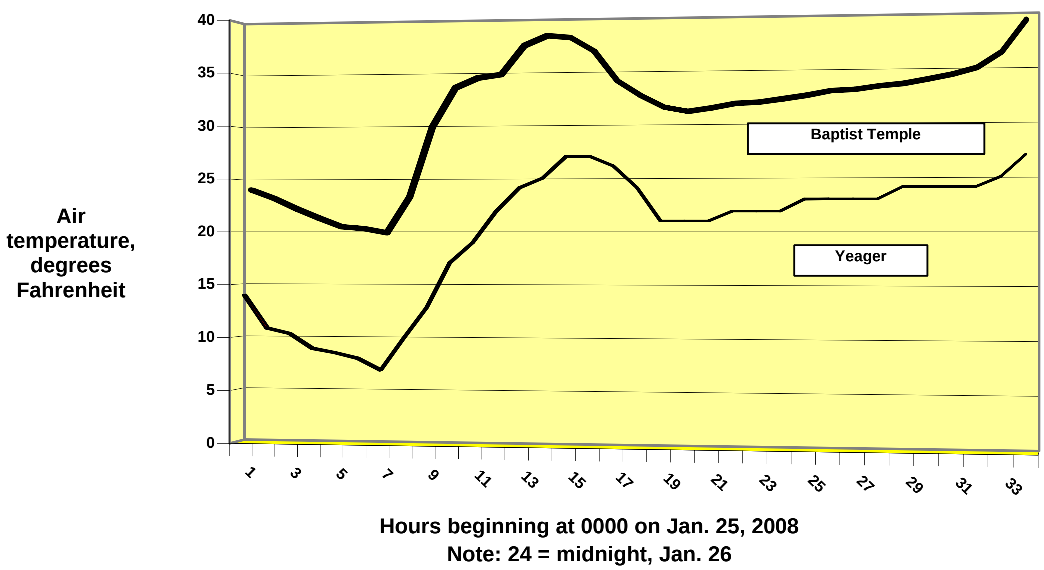
Based on data from the NWS, as well as from the DAQ meteorological-monitoring site in Institute, it appears two distinct microclimates—at Yeager Airport and higher elevations, and in the valley—appeared to form sometime between noon and 1 p.m., then continued through the rest of the day. These micro-regimes account for the differences in observations and gathered instrumentation data.

2.2.2. Temperature

Fig. 2-3 shows the hourly temperature readings for those two temperature regimes, starting at midnight, or 0000, on January 25 and ending at 10 a.m., or 1000, on January 26:

- The top line represents the Baptist Temple air monitoring site in downtown Charleston. Note that this monitoring station has no wind speed and direction sensors. However, it does have an ambient temperature probe, although it is not typically calibrated nor is its data quality assured. Also, the instrument is located approximately four feet above a roof having tar paper covered with gravel. Therefore, the data presented for this site serve only to show relative temperature differences between the valley and Yeager.

Fig. 2-3.
Comparison of Air Temperatures:
Yeager Airport and DEP Baptist Temple Air Monitoring Site
Midnight, or 0000, on January 25 - 10 a.m., or 1000, on January 26



- The bottom line represents the NWS observations reported at Yeager, which, according to Federal Aviation Administration information, is three miles east of Charleston and at a surveyed elevation of 981 feet above mean sea level.

2.2.3. Wind

Just as there appears to have been two temperature regimes, there appear to have been two distinct wind-pattern regimes.

According to the NWS, based on data taken on January 25 at Yeager, which is approximately 400 feet higher in elevation than the valley floor, the wind was calm, having no or essentially no direction and speed, from 3:54 a.m. to 11:54 p.m. Not until 9:54 a.m. on Saturday, January 26, did NWS change the classification. Then, that agency noted wind speed and direction were 4.6 miles per hour and south, respectively.

However, down in the immediate Kanawha River Valley, there appeared to be air movement. Fig. 2-4 shows the wind speeds measured in Institute on a DAQ 25-meter meteorological monitoring tower. The instrument height is approximately 22 meters, or approximately 72.2 feet, above ground level. Readings by the tower's instrumentation would be considered representative of ground-surface winds.

Fig. 2-5 shows the wind direction during January 25. Note the following about this graphic, which is called a wind rose:

- the bars indicate the direction from which the wind blew
- the colors of the bars indicate the wind speed
- the data at the rose's center indicates that, overall and according to the software which processes the data, winds were not calm at any point of the day

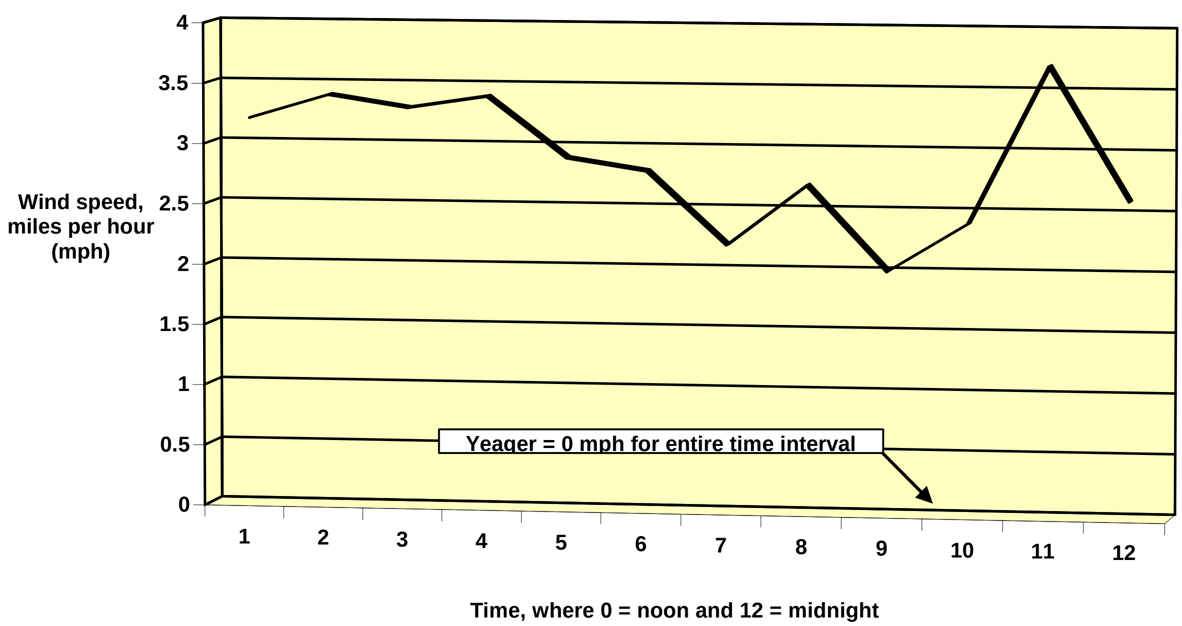
- west winds predominated throughout the day, with significant contributions from northeast, southeast and south-southeast winds

2.2.4. Visibility

The NWS described visible atmospheric conditions on January 25 as clear at the 5:54 a.m. and 6:54 a.m. readings, then again from 12:54 p.m. to 8:54 p.m. More specifically, during the day, the NWS described the visibility as unrestricted, with eight-to-10 mile visibility. Note, however, these are aviation-based observations made at Yeager Airport.

But at 8:54 p.m., the observation changed to scattered clouds.

Fig. 2-4.
Wind Speeds at DAQ's Meteorological Monitoring Station, Institute; and Yeager Airport, Charleston--January 25, 2008

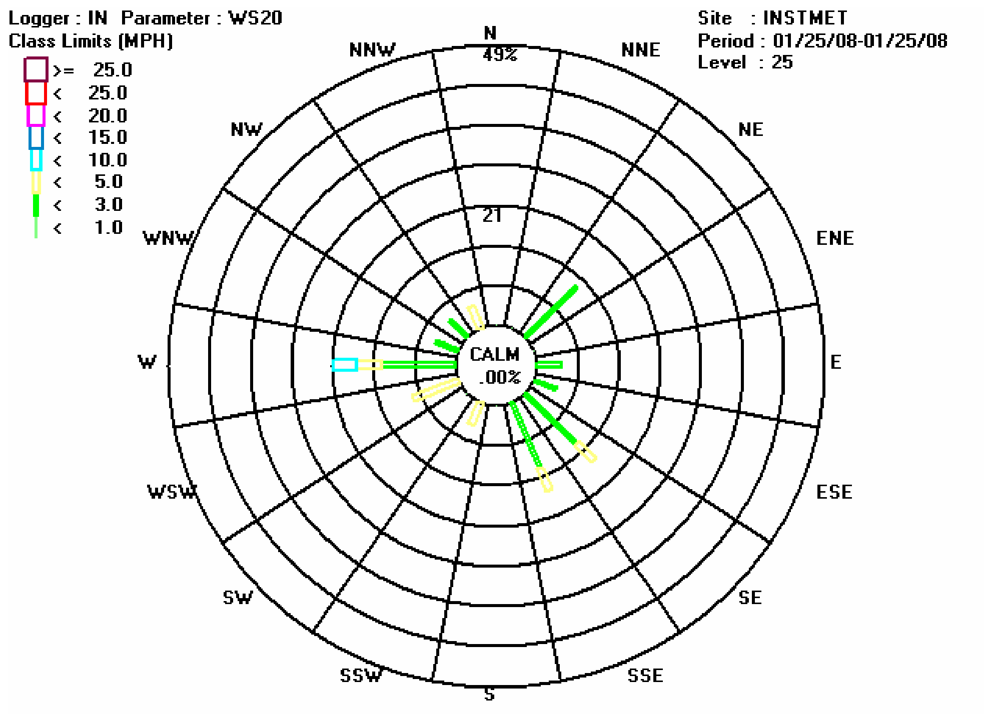


Then, at 9:54 p.m. January 25, NWS changed the classification to mostly cloudy. That classification remained until 2:54 a.m. January 26, when NWS changed the classification to overcast.

At 9:54 a.m. January 26, when NWS reported the wind had both speed and direction for the first time in 30 consecutive hours, the weather agency reported light snow, which appears to have lasted for no more than an hour. Note, again, this report is based on conditions at Yeager Airport.

Fig. 2-5.

Wind Rose For Institute, W.Va., on January 25, 2008
[Source: Data from WVDEP / DAQ 25-Meter Meteorological Monitoring Station]



Notes:
MPH = miles per hour
The color of the bars indicates the wind speed.
The length of the colored bars indicate the percent of the time, during this 24-hour period, that the winds blew from the direction given for that sector. For example, the winds at a speed less than 3 miles per hour blew from the west for approximately 13 percent of the total time. With the additional of west winds blowing at speeds of up to 5 and 10 mph, the total percent of time that winds blew from the west was approximately 21 percent. There were no periods of calm winds.

From 10:54 a.m. January 26, until 8:54 p.m. that evening, the NWS reported overcast skies.

2.2.5. Relative Humidity

At 11:54 a.m. on January 25, the NWS' weather summary from data measured at Yeager reported relative humidity was 62 percent.

One hour later, at 12:54 p.m. at Yeager, the NWS-reported relative humidity was 58 percent.

Then, over the next eight hours, the relative humidity ranged from 55 percent at 1:54 p.m. to a low of 45 percent at 4:54 p.m., then to 65 percent at 7:54 p.m., when the last clear classification of atmospheric conditions occurred on January 25.

CHAPTER 3
ASSESSMENT and CONCLUSIONS

The visual and olfactory impacts of the blue-haze incident require assessment and explanation. The impacts also raise questions as to why they occurred or what might have caused them.

Through gathering and analyzing data, including ambient air quality data; plant-specific data for selected sources such as the AEP-owned John Amos Power Plant; aerial photographs; and comments made by the public and DEP staff, the DAQ has sought to understand and clarify what occurred atmospherically January 25 in the Kanawha River Valley. This chapter presents DEP's assessment of what happened and its best judgments why.

3.1. Overall Assessment of the Incident

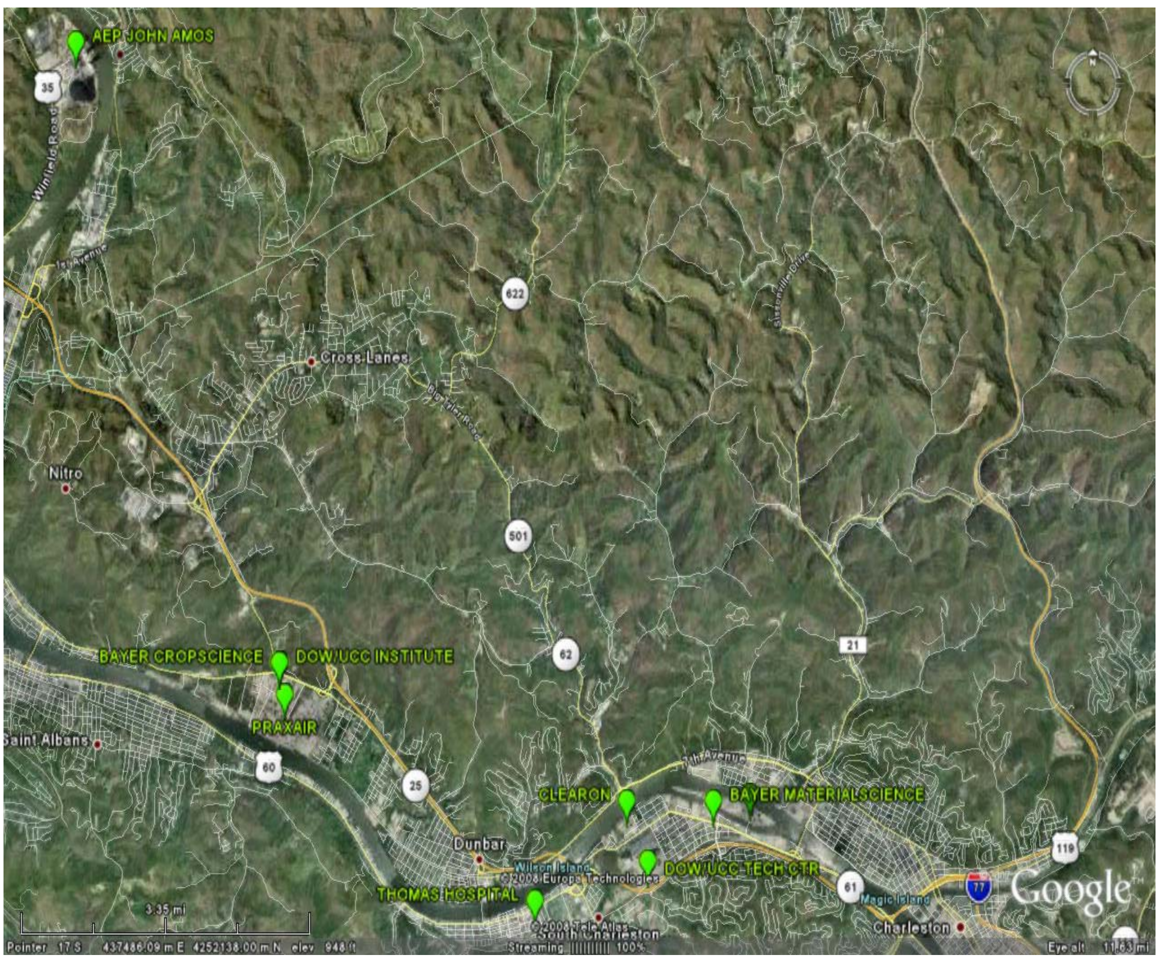
3.1.1. Emissions

Photographs 3-1 and 3-2 show, respectively, the approximate location of the major sources or facilities that produce air pollution from Charleston, downriver to the Amos plant; and the major facilities in the Dunbar-South Charleston area. The DEP notes that of the plants' stacks, those at Amos, which are approximately 900 feet tall, are the only ones that are higher than valley ridgelines.

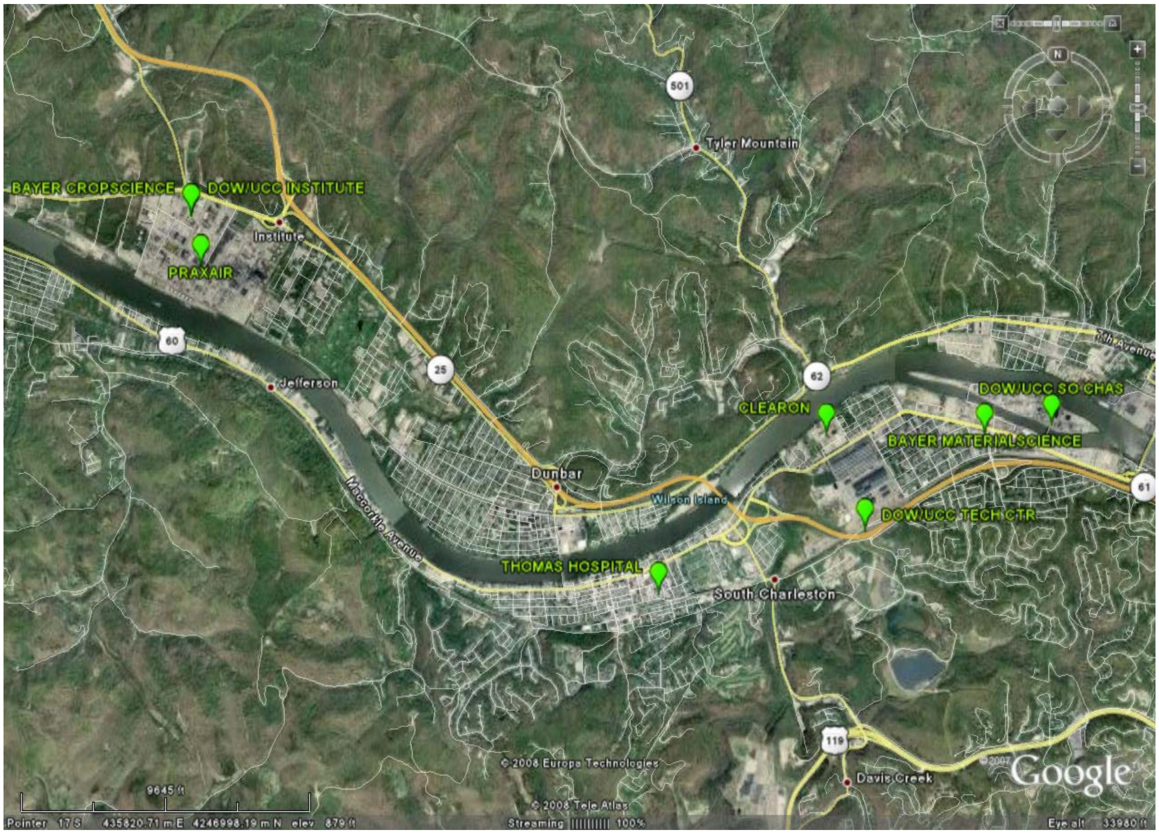
Excluding carbon dioxide, which is not a known contributor to visibility problems, the emission rates in Table 3-1 reasonably represent the total combined pollutants emitted hourly from that specific group of facilities. Note: Fig. 3-1 presents the percent contributions of these major sources to that hourly total.

- As shown, of the major stationary facilities in the portion of the Kanawha River Valley affected by the haze that likely could have contributed to the haze and/or odor, combined Amos plant emissions comprise approximately 94.3 percent of the hourly total.

- If all major stationary sources in Kanawha and Putnam counties are compared, regardless of their location, then the combined Amos plant emissions comprise approximately 84.8 percent of the total hourly emissions. Appendix A gives a 2006 summary of selected emissions—particulate matter; SO_2; NO_X; volatile organic compounds (VOCs); hydrochloric acid, or HCl; and sulfuric acid, or H_2SO_4—as well as the total of all emissions combined, from all major stationary facilities in Kanawha and Putnam counties, including the Amos plant.



Photograph 3-1. Approximate locations of the major air pollution-emitting facilities in the affected portion of the Kanawha River Valley that were operating January 25.



Photograph 3-2. Approximate locations of the major air pollution-emitting facilities in the Dunbar-South Charleston affected portion of the Kanawha River Valley that were operating January 25.

Based on those same 2006 emissions inventory data, the two most predominant pollutants emitted into the Kanawha-Putnam counties region from all major stationary sources, including these mentioned in Table 3-1, are SO_2 and nitrogen oxides, or NO_X. Both are combustion-related pollutants. Those estimates and other estimated total pollutant emissions, in pounds per hour (lb/hr), follow. Note: Regarding H_2SO_4 and HCl data, see Footnote B of Table 3-1:

- The SO_2 emissions comprise the most mass, at 33,275 lb/hr.
- The next most prevalent pollutant is NO_X, at 11,287 lb/hr.

Table 3-1

Estimated Per-Plant Combined Total Pollutants Emission Rate, Pounds/Hour, For Major Stationary Sources in the Kanawha River Valley, From Charleston to the John Amos Power Plant [Source: 2006 Emissions Inventory and Data Supplied by AEP]

MAJOR SOURCES IN KANAWHA RIVER VALLEY From Charleston to Winfield	**ESTIMATED COMBINED POLLUTANTS EMISSION RATE [A]** **Pounds per hour (lb/hr)**
American Electric Power Co / John Amos Power Plant, Winfield	44,125[B]
Bayer CropScience, Institute	1,858
Dow/Union Carbide Corp., South Charleston Facility	489
Dow/Union Carbide Corp., Institute	197
Bayer MaterialScience, South Charleston	54
Clearon Corp., South Charleston	31
Dow/Union Carbide Corp. Tech Center, South Charleston	28
Praxair Hyco Plant, Institute	19
Total	46,801
Percent of Total Combined Emissions Attributable to Amos Plant	94.3%

Notes:
[A]Not all facilities emitted the same number and/or types of pollutants.
[B]Some more current data for the Amos plant have been used. In March 2008, AEP submitted those newer data to the U.S. Environmental Protection Agency (EPA) Region III office for Amos plant H_2SO_4 and HCl. That March 2008 submittal updated information AEP had submitted to EPA in April 2000. The more recent submittal notified EPA of increases in the continuous-release estimates of these two compounds, as required by EPA through 40 Code of Federal Regulations Part 60 Subpart J: Superfund, Emergency Planning and Community Right-to-Know Programs. The newer data increased the upper bound, or maximum estimate, of the total emissions that were reported in AEP's 2006 emissions inventory data submitted to the DAQ.

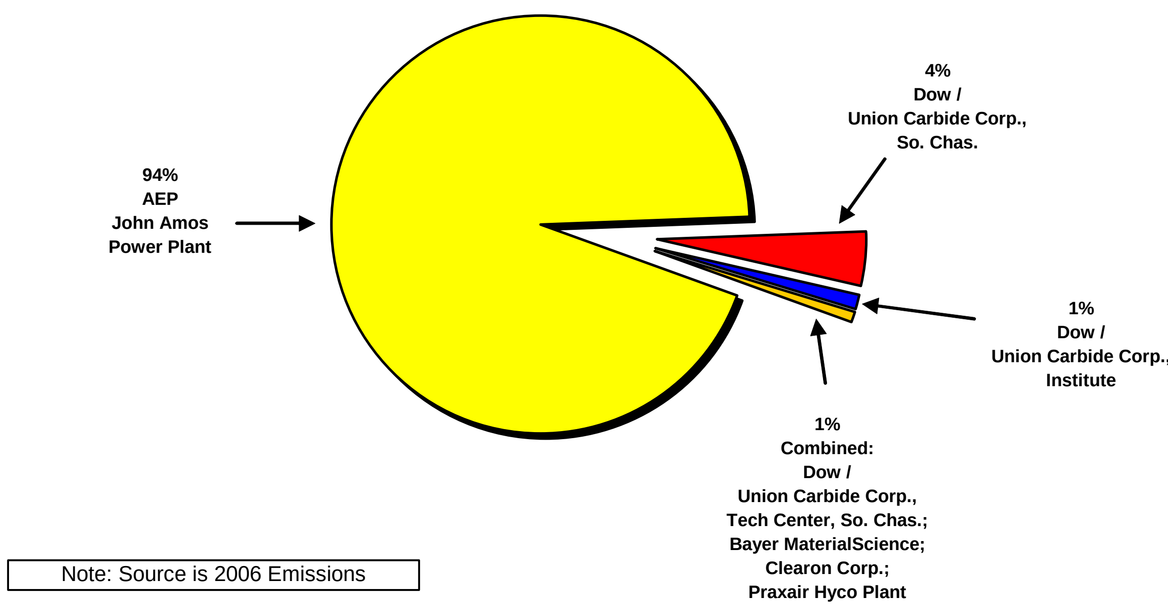
- HCl is the third most prevalent pollutant, at 3,525 lb/hr. Note that this does not include any estimated emissions from the AEP-owned Kanawha River plant, located at Glasgow, West Virginia.

- H_2SO_4 is the fourth most-prevalent pollutant, at 1,327 lb/hr. Note that this does not include any estimated emissions from the AEP-owned Kanawha River plant, located at Glasgow, West Virginia.

- Of the pollutants that may cause visibility issues, the next most prevalent pollutant is VOCs at 673 lb/hr.

- Following that is the smallest size fraction of PM, $PM_{2.5}$ at 471 lb/hr. As mentioned in Chap 2., $PM_{2.5}$, a subset of PM_{10}, is particulate matter having an aerodynamic diameter of 2.5 microns or less, which means the diameter is equal to or less than approximately 1/10,000th of an inch.

Fig. 3-1
Estimated Percent Contribution, to Nearest Whole Percent, of Major Stationary Facilities' Hourly Emissions in Affected Portion of the Kanawha River Valley During January 25, 2008, Blue-Haze Incident



3.1.2. Principal and/or Potential Industrial Contributors

Because there were two principal issues—haze and odor—to the air pollution episode, this section presents DEP's separate assessments of the facility or facilities that may have contributed to them.

3.1.2.1. Haze

While the DEP acknowledges that some unknowns still exist to determine what caused the blue-haze incident, the DEP believes a preponderance of evidence clearly shows the AEP-owned Amos plant, in Winfield, was a major contributor to the haze problem, once the inversion occurred. The DEP bases this conclusion on information discussed in this chapter, particularly Sections 3.1.1 and 3.2 through 3.6; as well as the information in Chap. 2 and DAQ's to-date observations and investigations.

- In the Kanawha River Valley, the Amos plant is the largest single emitter of $PM_{2.5}$. Particles at this size contribute to visibility impairment, through absorption and scattering of visible light. Fig. 3-2, while depicting how light absorption and scattering affect scenic views, shows important factors in how objects are seen.

- Amos is the Kanawha River Valley's largest single emitter of SO_2 and NO_X. Both chemical compounds, when atmospherically changed to sulfates and nitrates, respectively, contribute to haze because of their transformation into $PM_{2.5}$.

- Amos is the Kanawha River Valley's largest single emitter of both sulfuric acid and hydrochloric acid, both of which may be transformed into aerosols. These particles, which are classified as $PM_{2.5}$, can reflect or scatter light in the atmosphere, creating a blue-gray haze.

Based on the following, the DEP also concludes that the thermal inversion created fumigating conditions in the vicinity of Amos that created and then prolonged the blue-haze incident:

- A time-lapse video taken by a local television station's camera mounted atop a microwave tower in downtown Charleston visually captured the rapid change in atmospheric conditions, as well as the initial fumigation.

- The video showed a bluish haze moving steadily upriver from the Poca-Winfield area, where the Amos plant is located, obscuring more and more of the back-ground as it moved.

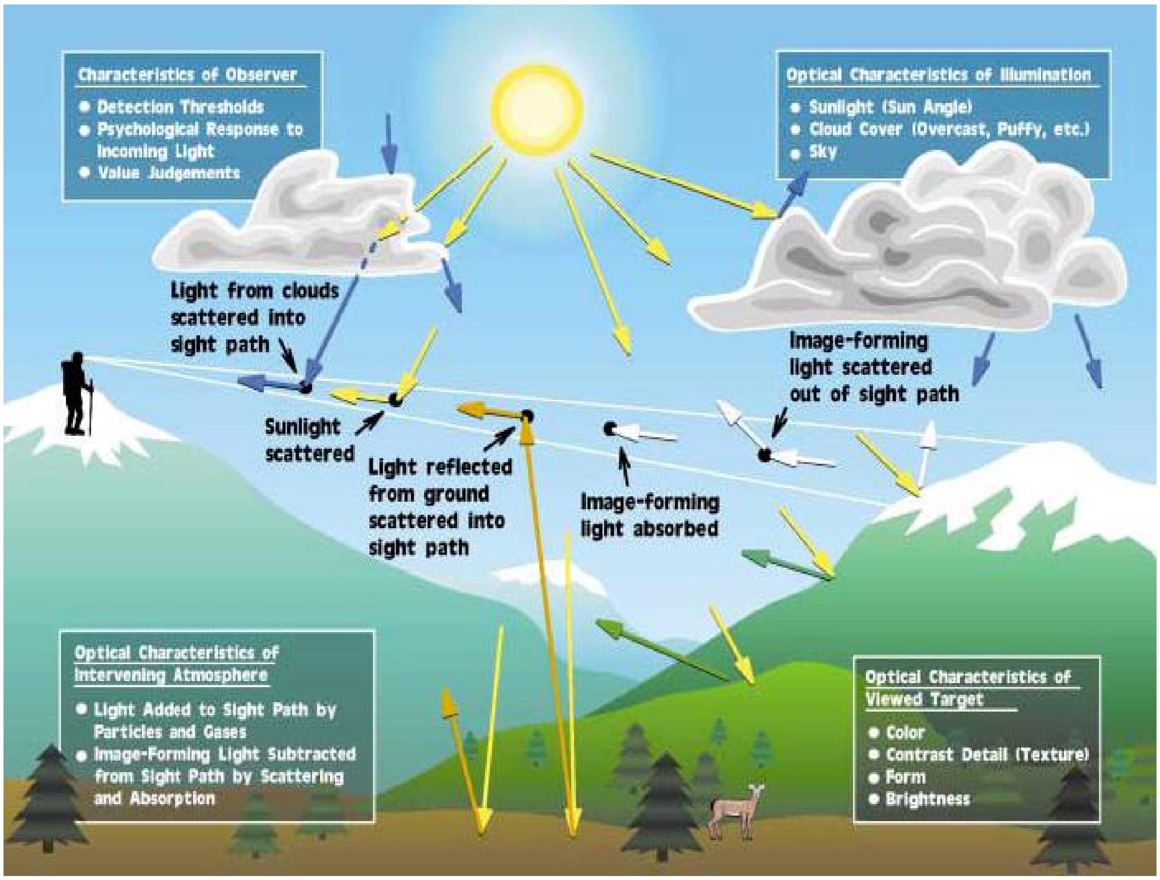


Fig. 3-2. Important Factors in Seeing an Object. Image-forming information from an object is reduced—that is, scattered and absorbed—as it passes through the atmosphere to the human observer. Air light is also added to the sight path by scattering processes. Sunlight, light from clouds and ground-reflected light all impinge on, or strike, particles and scatter from those particulates located in the sight path of an observer. Some of this scattered light remains in the sight path—and, at times, can become so bright that the image essentially disappears. A final important factor in seeing and appreciating a vista is the characteristics of the human observer. Source: Malm, William C., "Introduction to Visibility." National Park Service. Air Resources Division. May 1999.

- While the sulfuric acid emitted from the Amos plant as currently configured is vapor, which has no optical properties, the DAQ believes that on January 25 at-mospheric conditions, at some distance from the plant, transformed the vapor into an aerosol that refracts or reflects the blue part of the visible-light spectrum.

But the DAQ notes that regardless of the impact of combined categories of plant emissions—and given that all other operating stationary facilities' and mobile sources' emissions were trapped in the Kanawha River Valley until the inversion ended—the meteorological conditions that created the inversion likely would have led to some level of increased haziness in the Kanawha River Valley, even if the Amos plant had not been operating January 25.

The DAQ also notes that besides the major stationary facilities operating January 25 in the Kanawha River Valley, minor industrial, commercial, institutional and residential sources also operated.

3.1.2.2. Odor

Regarding the complaint of chlorine or bleach-like odors, while the source or sources of these odors remain unknown, potential sources south and west of downtown Charleston exist that could have contributed to that odor on that day. Those include not just the Amos plant, but Bayer CropScience in Institute, as well as Clearon Corp. and Dow/Union Carbide Corp., both in South Charleston.

However, DEP acknowledges and emphasizes the following about the stationary facilities just mentioned in preceding paragraphs, as well as all other stationary and mobile sources operating in the affected part of the Kanawha River Valley on January 25:

- None of the facilities mentioned, or any other stationary source in the Kanawha River Valley, reported any malfunction on January 25.

- None of the facilities mentioned, or any other stationary source in the Kanawha River Valley, reported on January 25 that any seals or gaskets on pumps, valves or any other such equipment ruptured or failed, causing an accidental release of any chemical—particularly one with a chlorine or chlorine-like odor.

- Through ground and aerial surveillance on January 25, the DEP observed no obvious and/or visible leaks of chemicals from any stationary facility in the Kanawha River Valley.

- Through direct telephone surveys of major sources that could have contributed to any odor complaint like those received at the DEP on January 25, the DAQ learned of no accidental spill or release of chlorine, any other chemicals with a chlorine or chlorine-like odor, or any other chemicals from those facilities.

- The DEP remains unaware of any report on January 25 of any accidental spill or release of chorine, any other chemicals with a chlorine or chlorine-like odor, or any other chemicals from any mobile source in the Kanawha River Valley.

- Minor industrial, commercial, institutional and residential sources also operated in the Kanawha River Valley on January 25.

3.2. Thermal Inversion and Urban Haze-Hood

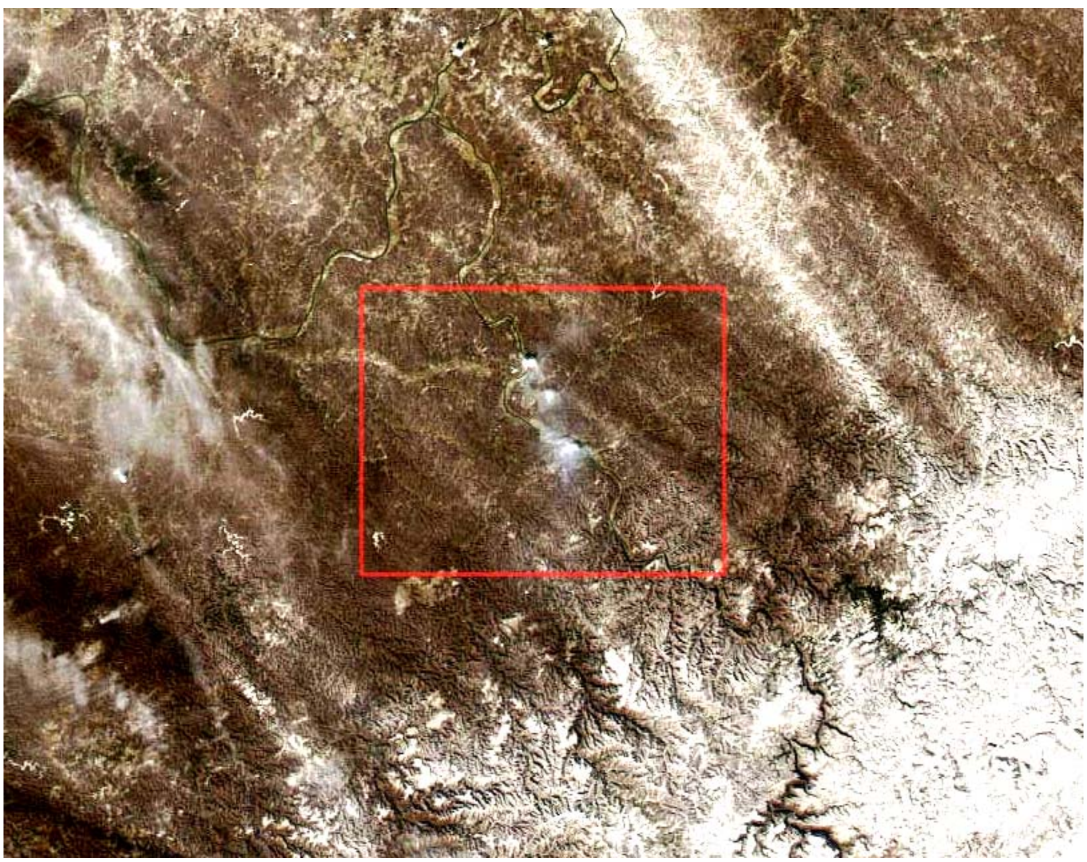
As mentioned in Chap. 2.2.1, the abrupt change in atmospheric conditions at midday January 25 was due to a meteorological condition called an inversion. It trapped air pollutants in the Kanawha River Valley, causing ambient concentrations of air pollutants to rise. Additionally, urban conditions also appear to have induced an urban haze-hood, an inversion-related phenomenon that further aggravated the impact of the inversion on visibility and concentrations of pollutants in ambient air.

The following summarizes the DEP's perspective on the atmospheric changes that occurred January 25:

- A thermal inversion occurred, causing rapid air stagnation and continuously trapping air pollutants in the Kanawha River Valley for hours.

- Based on a satellite photograph taken January 25, see Photograph 3-3, as well as ground- and aerial-surveillance observations made by DEP staff, it appears the air mass that stagnated was generally bounded downriver of Charleston by the Amos plant and upriver of downtown Charleston by the 35th St. Bridge.

- That same satellite photograph shows that the trajectory or route of the combined exhaust-stack and cooling-tower plumes from the Amos plant approximates a straight line between the Amos plant and South Charleston, with the Elk River and downtown Charleston to the northeast of the eastern terminus of that trajectory.



Photograph 3-3. Satellite image of the Kanawha River Valley during the afternoon of January 25. In the middle of the red box, the bright white spot left of upper center is the Amos plant's combined exhaust-stacks and cooling-tower plumes. The terminus of that plume is approximately over South Charleston, with Charleston and the Elk River discharge into the Kanawha River northeast of the trajectory's eastern terminus (nearest the right bottom corner of the red box).

- The urban haze-hood created an upward flow of pollutants in this dome or hood, to the ceiling of the dome, where the polluted air spread out, cooled and then sank at the edges of the dome. Cool air from the dome's edge flowed into the center to replace the rising hot air, thus creating a recirculation system of polluted air.

- Aided by the thermal inversion, that urban haze-hood-induced flow helped concentrate and then recycle air pollutants in the Charleston metropolitan area, at least from the Institute-St. Albans area upriver toward and into downtown Charleston.

- Cold-air drainage down the Elk River Valley into the Kanawha River Valley appears to have established an upriver barrier that initially and substantially prevented the incident from spreading farther upriver beyond Charleston.

3.3. Valley Wind Patterns

Based on data taken from the DAQ's 25-meter meteorological monitoring tower in Institute, and as discussed in Chap. 2, two microscale climates appear to have occurred January 25 in the Charleston metropolitan area.

- Within the immediate valley, there appeared to be significant difference in visibility and odor west of the 35th St. Bridge, toward downtown Charleston, and east of the bridge, toward eastern Kanawha City and Belle.

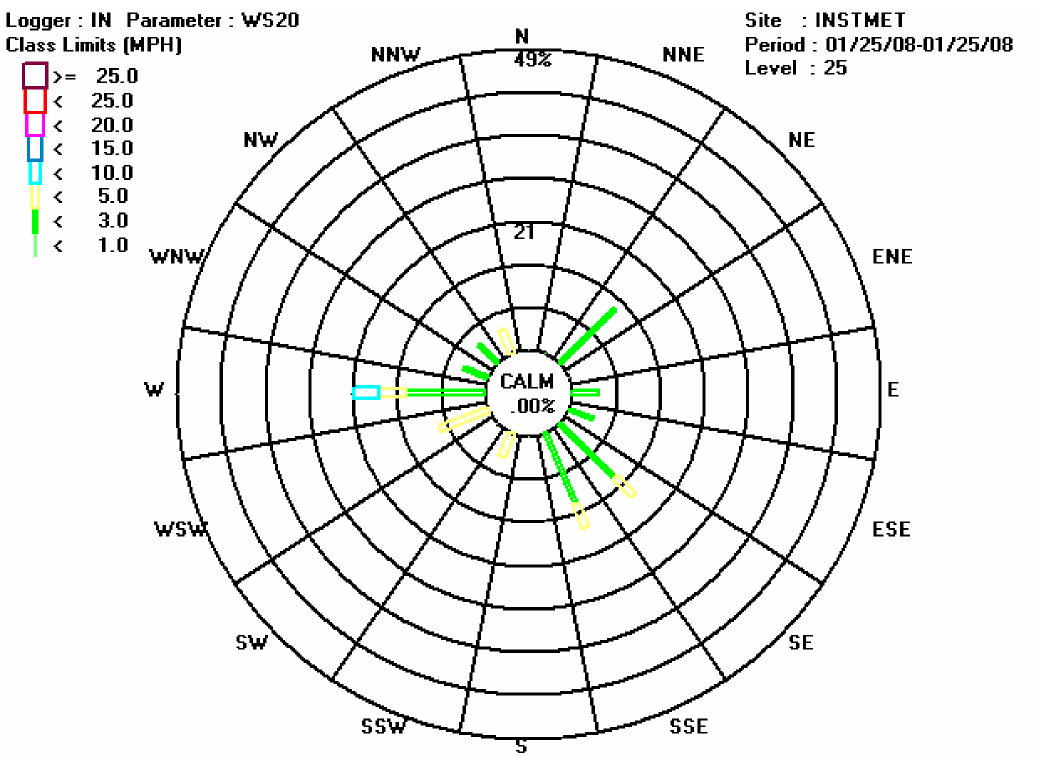
- The winds that predominated on January 25 in the affected portion of the Kanawha River Valley were from, in descending order of frequency and duration, the west, northeast, southeast, south-southeast and west-southwest.

- As shown on Fig. 3-3, of the 16 sectors in which wind direction and speed are recorded, winds blew for some duration on January 25 in all but two sectors. There were no calm winds, unlike NWS data show at Yeager.

- These in-the-valley winds would have intensified the movement of pollutants into and out of the air mass contained within the urban haze-hood. Table 3-1—which contains the most current list of major sources of or facilities emitting air pollution in the affected portion of the Kanawha River Valley and those sources' emissions—shows that there were other potential stationary source contributors than those already mentioned, though the Amos plant emissions predominated.

- The combined west wind and recirculation pattern created by the urban haze-hood blew and induced, respectively, pollutants from the Amos power plant into more densely populated areas upriver.

Fig. 3-3.
Wind Rose For Institute, W.Va., on January 25, 2008
Data Source: WVDEP / DAQ 25-Meter Meteorological Monitoring Station



Notes:

MPH = miles per hour
The color of the bars indicates the wind speed.
The length of the colored bars indicate the percent of the time, during this 24-hour period, that the winds blew from the direction given for that sector. For example, the winds at a speed less than 3 miles per hour blew from the west for approximately 13 percent of the total time. With the addition of west winds blowing at speeds of up to 5 and 10 mph, the total percent of time that winds blew from the west was approximately 21 percent.
"Calm .00%" indicates no periods of calm winds.

3.4. Amos Plant Combined Plume Fumigation

The DEP believes that underneath the inversion, particularly at the boundary layer between the two microclimates, the Amos plant's combined cooling-towers and boilers-exhaust-stacks plumes played a significant role in the visibility aspect of the blue-haze incident, through a condition called plume fumigation.

With a thermal inversion like the one of January 25, unless plumes from stationary sources of air pollution have the thermal and mechanical momentum to penetrate through the inversion, they have to disperse laterally. They do so until they have no energy to disperse further laterally or in some other direction having both lateral and vertical components.

Using 2006 inventory data, as well as its own calculations of the sulfuric acid from the Amos plant, based on information supplied by AEP (see Section 3.6.2 and Appendix B), DAQ believes the following reasonably approximates the Amos plant emissions on January 25. Note, however, that these estimates do not account the volume of the 2,000 gallons of bleach, used an as algicide, that AEP puts into the cooling towers each Thursday and Monday:

- 3,278 lb/hr of HCl, which is a maximum estimate from a recent disclosure by AEP to EPA Region III
- 1,327 lb/hr of H_2SO_4, which is a maximum estimate from a recent disclosure by AEP to EPA Region III
- 28,732 lb/hr of SO_2
- 8,315 lb/hr of NO_X
- 504 lb/hr of PM_{10}-primary, which includes what is known as both condensable and filterable PM_{10}
- 328 lb/hr of $PM_{2.5}$-primary, which includes what is known as condensable and filterable $PM_{2.5}$

Typically, the lower edge or boundary of a fumigating plume will touch down at the ground surface at some distance from the stack(s), while the upper boundary of the plume travels laterally along the bottom of the inversion layer. This type of dispersion is called fumigation.

DAQ surmises that the thermal inversion created fumigating conditions in the vicinity of Amos. A time-lapse video taken by a local television station's camera mounted atop a microwave tower in downtown Charleston visually captured the rapid change in atmospheric conditions, as well as the initial fumigation. The camera's perspective was looking downriver, toward the chemical complexes of South Charleston and Institute, as well as the Amos plant a few miles farther downriver. The video showed a bluish haze moving steadily upriver from the Poca-Winfield area, obscuring more and more of the background as it moved.

The following support the DEP's contention that fumigation most likely occurred:

- Aerial photographs taken during the DEP's first aerial reconnaissance over the Nitro-Cross Lanes area show little, if any, haze in that immediate area. See Photograph 3-4.

Photograph 3-4. Looking north from above Institute. Note the Cross Lanes Wal-Mart at the photograph's center. Note, too, the Amos plant at the extreme northwest edge of the upper left quadrant of the photograph.

- Also taken from the helicopter as it flew toward the Amos power plant, aerial photographs above the Nitro area toward Institute and Charleston show little haze in the Institute area, but haze in the distance, toward South Charleston and Charleston. See Photograph 3-5.

Photograph 3-5. Looking southeast from above Nitro. Bayer CropScience in Institute is in the foreground. South Charleston and Charleston are in the upper right quadrant of the photograph. The Amos plant is outside the frame of the photograph, northwest of the center of the photograph.

- Given the fumigation that occurred, this clear area would indicate that the Amos plume had touched down further upriver, toward Institute and Charleston, or, if it had touched down in this area, it appeared not to be doing so any longer.

- Photograph 3-6 shows the impact of the inversion at the Amos plant, approximately two and a half hours after DAQ received its first complaint.

- Photograph 3-7, which was taken within minutes of Photograph 3-4, shows how the exhaust-stacks and cooling-towers plumes mixed, and the general effect of the inversion layer.

Photograph 3-6. Looking northeast from above the St. Albans exit on Interstate 64 West. Note that the active boiler exhaust stacks—the two most slender of the four taller stacks shown—are approximately 900 feet tall. That would indicate that the inversion layer above the plant was approximately 2,500-3,000 feet above the Kanawha River Valley floor. Note, too, that Charleston would be considerably to the right of the plant, to the east, outside of the frame.

3.5. Haze

Regardless of its descriptors, the blue haze that filled the Kanawha River Valley on January 25 remains evidence of the incident's impact on the valley and some adjacent areas. Note, though, that the incident might more properly be called the blue-mist incident since mists—which are formed of fine particles called aerosols—give a bluish-gray color, which was evident in the Kanawha River Valley on January 25, as opposed to a haze, which tends to be brownish.

Photograph 3-7. Looking north from above Institute. Note the Cross Lanes Wal-Mart in the foreground. Note also: The active boiler exhaust stacks—the two most slender of the four taller stacks shown—are approximately 900 feet tall. That would indicate that the inversion layer above the plant was approximately 2,500-3,000 feet above the Kanawha River Valley floor.

However, on January 25, there were locations where commingling of bluish and brown colorations appeared. Generally, though, most people would not be so precise in differentiating haze from mist. Therefore, the DEP continues to call the January 25 episode the blue-haze incident. Note that the degree of visibility impairment by haze depends on the following: concentration, size and chemical composition of the fine particles in the atmosphere, as well relative humidity and the angle at which sunlight penetrates the haze.

Regarding observations of the haze that occurred January 25, the DEP notes that even in the part of the Kanawha River Valley where the blue haze occurred, an observer's perception of the haze and its intensity depended on that observer's physical location in the valley and/or elevation above it—and particularly on the observer's position and orientation relative to the sun.

In spite of an observer's location, though, the DEP believes the points listed below explain the predominant bluish coloration of the atmosphere on January 25, beneath the inversion layer. Note that the DEP has not included sources of potential haze contributors, such as coniferous trees or some others, because the agency does not believe these would have had much measurable contribution, if any, to the episode.

- Generally, dust and smoke in the atmosphere may create a bluish haze, but its intensity depends on the number of particles, their mass and their optical properties.

- Aerosols, which are minute particles created by natural activities such as wind-blown dust and human activities such as fossil-fuel combustion, are suspended in the atmosphere. Aerosols, which are at least $PM_{2.5}$ or smaller, produce haze through their mass concentration and particle count because their optical properties scatter or absorb sunlight.

- Sulfates associated with fossil-fuel combustion, especially coal and oil, are a major factor in atmospheric haze. These pollutants, which are created in the atmosphere from SO_2, may scatter light more during humid conditions.

- Other haze contributors include nitrates, which are formed atmospherically from NO_X, a combustion-generated pollutant; as well as particulate matter such as $PM_{2.5}$, which can be emitted directly from stacks of combustion sources.

- Other potential contributors to blue haze or brownish haze, which was also observed on January 25, include VOCs. These may be released into the atmosphere by the evaporation of fuels, such as gasoline at filling stations; incomplete combustion of fossil fuels in internal combustion or diesel engines, boilers or incinerators; and evaporation of solvents. The VOCs photochemically react with NO_X and form what is commonly called smog. DAQ notes that its Kanawha River Valley VOC monitor, which is co-located with the PM_{10}, $PM_{2.5}$ and SO_2 monitors atop the Baptist Temple in downtown Charleston, was inoperative January 25. Therefore, DAQ has no means of determining if VOC levels rose in the urban area and, if so, to what level.

- Ambient air quality data at two monitoring sites, one in South Charleston and one at the Baptist Temple in downtown Charleston, show elevated $PM_{2.5}$ levels during the incident: 34.1 micrograms of $PM_{2.5}$ per cubic meter of air sampled ($\mu g/m^3$) at Baptist Temple; and 49.7 $\mu g/m^3$ at South Charleston, which is an exceedance of the EPA 24 hour NAAQS of 35 $\mu g/m^3$. The 49.7 $\mu g/m^3$ reading is the highest value recorded at the South Charleston site since 2002.

- The $PM_{2.5}$ data from the Baptist Temple and South Charleston sites represent approximate increases of 200 to 250 percent in 24-hour readings at Baptist Temple and South Charleston above what is normally measured during winter at these sites. For example, on Monday, January 28, the 24-hour $PM_{2.5}$ readings at Baptist Temple and South Charleston were 15.2 $\mu g/m^3$ and 19.9 $\mu g/m^3$, respectively.

- As shown in Fig. 3-4, PM_{10} and SO_2 values at the Baptist Temple site rose significantly during the incident. Note, though, there was no violation of those ambient air quality standards.

- It is reasonable to assume that the trapping of combustion gases and their associated pollutants from stationary sources was a significant, if not the primary, cause of the increased measurements of those two pollutants on January 25.

- DAQ also operates an adjacent speciation monitor in South Charleston that collects $PM_{2.5}$ particulate for coinciding 24-hour periods. This speciation monitor likewise recorded a value of 49.7 $\mu g/m^3$, which is the highest value experienced at the site since operations began in 2003. The speciation monitor *is not* used to determine compliance with the NAAQS, but rather to determine the chemical composition of the material on the speciation filter thereby providing information about the corresponding makeup of the material collected on the $PM_{2.5}$ filter. The speciation analysis indicates that sulfates contributed 26 µg/m^3, or 53%, to the total mass concentration. Secondary sulfates are formed from sulfur dioxide emitted during the combustion of fossil fuels. The January 25 speciation sample produced the highest sulfate value recorded since the DAQ began speciation monitoring there in 2003. Average January sulfate values in the years 2004 through 2007 range from 2.5 to 3.4 µg/m^3.

- Laboratories analyze the speciation filter to measure elemental compounds using X-Ray Fluorescence (XRF). The analytical results for the speciation filter indicate that elemental sulfur comprises 8.4 µg/m^3, or 17%, of the total $PM_{2.5}$ mass concentration. This is the highest sulfur value recorded since the speciation monitor was placed in service in 2003. Average sulfur values in the month of January in the years 2004 through 2007 range from 0.8 to 1.1 µg/m^3. Sulfur is a byproduct of fossil fuel combustion.

- Nitrates from the speciation filter are also analyzed. Nitrate concentrations on January 25 were 5.6 µg/m^3 or approximately 11% of the total mass. This was the second highest value recorded by the speciation monitor, just slightly lower than the highest value ever recorded of 5.7 µg/m^3. Average January nitrate values in the years 2004 through 2007 range from 1.0 to 1.9 µg/m^3. Secondary nitrates are formed from oxides of nitrogen that can be emitted when burning fossil fuels.

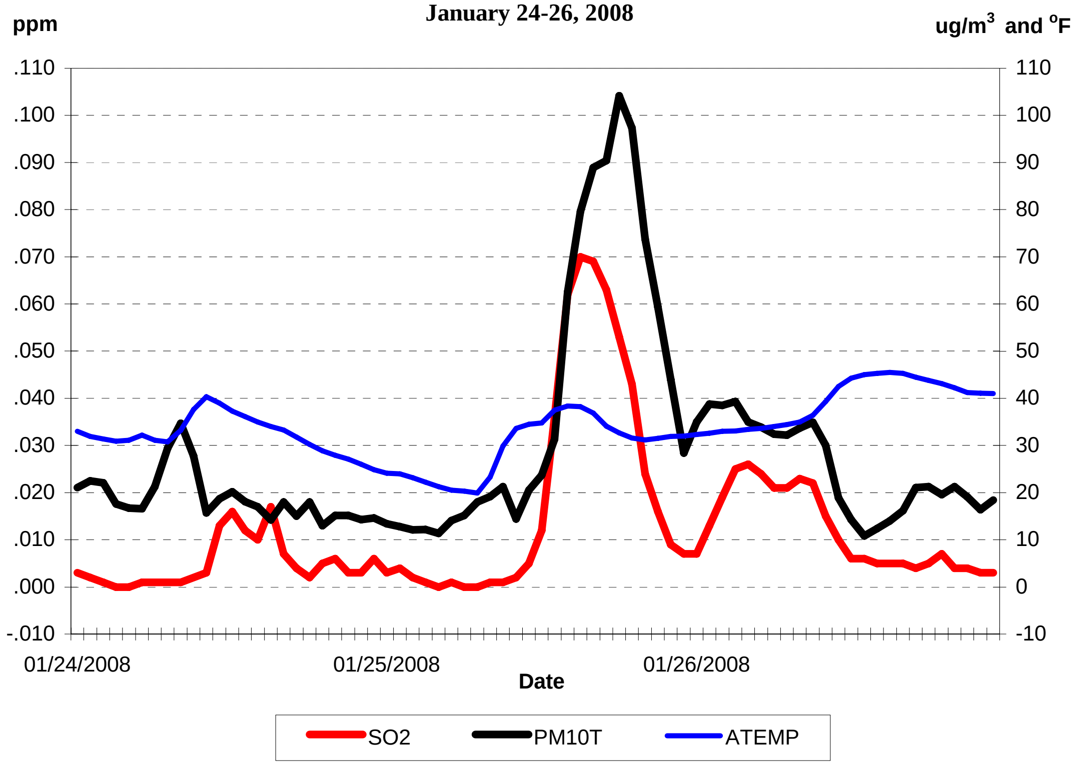
- Finally, using XRF, the laboratory measures various trace metals, including selenium which is considered to be a marker for coal fired combustion. Notably, on January 25, the selenium peaked at the highest value measured at the site since operations began in 2003. This points to coal-fired combustion sources as significant contributors to the parallel high values of sulfur, sulfates and particulate matter.

- While fossil-fuel-fired combustion sources and gasoline- and diesel-powered vehicles, locomotives and barges generate $PM_{2.5}$, the particulate matter emissions generated by the Amos plant's three boilers overshadow all other sources in the trajectory of a plume from the Amos plant to downtown Charleston. These three boilers—two which are rated at 800 megawatts (MW) of electricity generating capacity and one at 1,300 MW—are among the largest coal-fired utility boilers in the world.

- In the Kanawha River Valley, the Amos plant is the largest single emitter of $PM_{2.5}$ as well as SO_2 and NO_X. The latter two, when atmospherically changed to sulfates and nitrates, contribute to haze. Note that $PM_{2.5}$ from exhaust stacks is generally called primary $PM_{2.5}$, while the sulfates and nitrates are called secondary $PM_{2.5}$.

- Appendix C contains Figs. C-1, C-2 and C-3 that show increases in these pollutants on January 25 in the ambient air. The latter two figures show, respectively, $PM_{2.5}$, sulfates and nitrates measurements taken at South Charleston and the Guthrie Agricultural Center, a rural monitoring site located outside of the immediate Kanawha River Valley. Fig. C-1 indicates that the South Charleston $PM_{2.5}$ data were the highest of all three sites, including Baptist Temple, on January 25. Comparing Fig. C-2, for South Charleston, to Fig. C-3, for Guthrie, shows that for atmospheric sulfates and nitrates, the South Charleston site monitored the highest value on January 25.

Fig. 3-4.
PM_{10} and SO_2 Readings at Baptist Temple Ambient-Air-Monitoring Site, Charleston
January 24-26, 2008



Notes:

ATEMP equals air temperature at the monitoring site; PM10T equals total PM_{10}.
ppm equals parts per million
ug/m^3 equals micrograms per cubic meter (one microgram equals approximately 4/10,000,000th of an ounce; or 0.0000000353 ounces)
^{o}F equals degrees Fahrenheit
The National Ambient Air Quality Standard (NAAQS) for PM_{10}, for a specified 24-hour period, is 150 µg/m^3.
The NAAQS for SO_2, for a specified three-hour period, is 0.5 ppm.
The NAAQS for SO_2, for a specified 24-hour period, is 0.14 ppm.
The 24-hour NAAQS for SO_2 is the primary standard.

- Though smaller in emission rates than the Amos plant, other non-Amos stationary combustion sources exist that have significant combustion gases and related pollutants. The next largest source is the AEP-owned Kanawha River Plant, which is approximately 21 miles upriver of Charleston and which has approximately one-tenth the total generating capacity as the Amos plant. Though smaller than the Kanawha River plant's coal-fired boilers, the industrial boilers at DuPont in Belle and Dow/Union Carbide in South Charleston are also significant sources of combustion-related pollutants.

- In the combined fumigating Amos plume, potential contributors to visibility and/or odor problems include the approximate emissions of the following pollutants. These data were presented earlier in Section 3.4 Note, however, that DAQ does not speculate on what percent of each pollutant's hourly mass emissions would have been in a fumigating plume that moved upriver toward downtown Charleston:

    - 3,278 lb/hr of HCl, which is a maximum estimate from a recent disclosure by AEP to EPA Region III
    - 1,327 lb/hr of H_2SO_4, which is a maximum estimate from a recent disclosure by AEP to EPA Region III
    - 28,732 lb/hr of SO_2
    - 8,315 lb/hr of NO_X
    - 504 lb/hr of PM_{10}-primary, which includes what is known as both condensable and filterable PM_{10}
    - 328 lb/hr of $PM_{2.5}$-primary, which includes what is known as condensable and filterable $PM_{2.5}$

Observations made by the supervisor and the DAQ engineer involved in the aerial surveys support the extended upriver impact of the Amos plant's emissions.

- During one or both aerial surveys, the supervisor and/or the DAQ engineer-photographer recalled a smell and taste similar to flue gas when they were near the Amos plant, regardless of their altitude below the inversion layer. This occurred twice with the supervisor, who, along with the chief of Emergency Response, made both aerial surveys: the first from approximately 3:30 to 4 p.m.; the second from approximately 5:15 to 6 p.m.

- On his way home later, at 9 p.m., at the intersection of Jefferson Avenue and Kanawha Turnpike in South Charleston, the supervisor smelled the same odor and taste similar to flue gas. The odor had apparently infiltrated the passenger com-

> partment of his vehicle because the heating system was operating. He remembered the odor being the strongest he had encountered on January 25, even during the aerial reconnaissances. He also indicated that the strong taste associated with the smell was also just as powerful as it had been while traveling up and down the Kanawha River Valley, at different elevations, in the helicopter.

But the DEP also notes that mobile gasoline- and diesel-power combustion sources such as motor vehicles, barges, trains, highway tractor trailers or tankers, etc., would have contributed to haze. However, the specific impact on the color and/or density of the haze by these sources is unknown.

With regard to the blue haze and what gave it that specific color, DEP believes that one specific component of the Amos boilers' exhausts, the sulfuric acid or H_2SO_4, may have been the principal contributor.

3.6. Blue Plume

State and federal environmental protection agencies, as well as industry, particularly coal-fired power generation, have known for some time about the blue-plume phenomenon. This visual phenomenon occurs when power plants burn sulfur-containing coal and/or when those power plants use certain types of air-pollution-control equipment.

3.6.1. Background

The blue plume arises from sulfur trioxide (SO_3). Historically, it came from two sources in coal-fired power-plants: from the oxidation of sulfur during combustion of sulfur-containing coal; and through use of a performance enhancement in electrostatic precipitators (ESP), to lower the electrical resistivity of particulate matter, thus making its collection easier and more complete. The DEP notes it is generally expected that 1-2 percent of the sulfur in the combusted coal converts to SO_3. DEP also notes that a practice called SO_3 conditioning, which is the use of SO_3 injection in the gas stream to enhance ESP performance, ceased years ago at the Amos plant.

The equation for the combustion of the sulfur in the coal is as follows:

$$S \text{ (solid)} + O_2 \text{ (gas)} \xrightarrow[\text{heat}]{} SO_2 \text{ (gas)}$$

$$\text{Similarly, with heat: } 2\,S \text{ (solid)} + 3\,O_2 \text{ (gas)} \longrightarrow 2\,SO_3 \text{ (gas)}$$

However, at the Amos plant and other coal-fired power plants having selective catalytic reduction (SCR) units to reduce NO_X emissions, the SCR units typically convert 1 to 2 percent of the SO_2 to SO_3. DEP notes that on January 25, the SCR units for the 1,300-MW Amos Unit 3 and 800-MW Unit 1 were operating, while the SCR unit for 800-MW Unit 2 was not operating.

In the SCR, the SO_2-to-SO_3 conversion occurs as the SO_2-and-NO_X-laden exhaust gas, which also contains particulate matter as well as SO_3, exits the boiler and then passes through and over the SCR control unit's catalyst beds. These are rigid rectangular-shaped containers that have materials that convert the NO_X to N_2 and water. The following equation describes the conversion reaction of SO_2 to SO_3 in this process:

$$2\,SO_2 \text{ (gas)} + O_2 \text{ (gas)} \xrightarrow[\text{catalyst}]{} 2\,SO_3 \text{ (gas)}$$

The 1-to-2-percent conversion rate across the catalyst bed means that an additional 1 to 2 percent of the sulfur (S) in the coal fed into the boiler is converted to SO_3. Thus, the effect of the SCR catalyst bed may nearly double the amount of SO_3 generated in the boiler combustion chamber. Therefore, approximately 2 to 4 percent of the total sulfur content of the combusted coal converts to $SO_{3,}$ in coal-fired boilers with SCR units such as those at the Amos plant.

The SO_3 generated in those SCR air pollution control devices and the boiler—and, if present, an SO_3-conditioning system with an ESP—then combines with water, or H_2O, in the exhaust gas to produce H_2SO_4, or sulfuric acid. The equation that describes the overall reaction is as follows:

$$SO_3 \text{ (gas)} + H_2O \text{ (gas/vapor)} \longrightarrow H_2SO_4 \text{ (gas)}$$

But at coal-fired plants such as Amos that have no current wet flue-gas-desulfurization (wet FGD) unit operating on any of their boilers, the sulfuric acid created as a result of the combustion of coal and conversion across the SCR catalyst beds exits the stack as vaporous sulfuric acid.

At some distance from the stack, though, the vapor transforms into an acid mist or aerosol. The transformation depends on temperature, humidity and turbulence; as well as the presence of cooling-tower plumes and fine particulate matter. The resulting aerosol is highly refractive, which means it easily reflects light and especially in the blue part of the visible spectrum. Consequently, observers might see what is known as a blue plume.

Note, too, that given the thermal shock that occurs when the hot exhaust enters cooler ambient air, some acid mist or aerosol could form at the edges of the exhaust-gas stream, and could be visible.

In most cases, when a wet FGD unit is used, essentially all of the sulfuric acid vapor in the combustion gas transforms into acid mist or aerosol before being emitted to the atmosphere. The transformation occurs just upstream of the actual wet FGD vessel, when water sprays cool the gas stream. In this quenching process, the sudden and dramatic temperature drop thermally shocks the sulfuric acid vapor. That shock transforms the vapor to an aerosol that would be classified as $PM_{2.5}$ and whose particular particle size may be approximately 100 times less than the typical diameter of human hair (70-100 microns).

Because of their small size, these mist or aerosol particles pass essentially uncaptured through the wet FGD and into the exhaust stack, where they then vent to the atmosphere.

Then, depending on atmospheric temperature, turbulence and humidity, as well as particulate matter concentration in the exhaust gas and atmosphere, a blue plume may be seen at the stack's exit or at some distance from the stack exit. The former situation is called an attached plume; the latter is called a detached plume.

On a clear day such as January 25, when sunlight struck the aerosol that the DEP believes formed from the Amos plant emissions, the aerosol scattered the light, reflecting the blue part of the visible spectrum. Hence, the visible blue plume.

3.6.2. Amos Plant Contribution

Though the approximate amount remains unknown, several thousand pounds of sulfuric acid were emitted on January 25 within the combined Amos plume.

During the week of January 28, DAQ engineers estimated the amount. To do so, they used stack-gas-SO_3-concentration data requested and received from AEP, as well as exhaust-gas-flow data that AEP reported directly to the EPA Clean Air Markets Division, as part of the federal Acid Rain Program. The engineers calculated the upper bound of the combined mass of H_2SO_4 emitted daily from Amos Units 1, 2 and 3 at approximately 17,454 pounds, which equals approximately 727 lb/hr. Appendix B contains data and graphs used to make those calculations, as well a copy of the memorandum to the DAQ director with an engineer's analysis.

That rate was considerably higher than the combined upper-bound values AEP had submitted to EPA Region III in an April 12, 2000, letter. The company submitted those data to EPA, as required through 40 Code of Federal Regulations Part 60 Subpart J: Superfund, Emergency Planning and Community Right-to-Know Programs. For upper bounds, AEP indicated that stack number 1, which exhausts Amos Units 1 and 2, emitted 2,317 lb/day; and that stack number 2, which exhausts Amos Unit 3, emitted 1,784 lb/day. The estimated upper bound of the combined estimated daily rate was, therefore, 4,101 lb/day, which equals approximately 171 lb/hr.

But newer AEP data, which the company submitted March 6, 2008, to EPA Region III, substantially exceed those 2000 estimates for sulfuric acid (and, incidentally, hydrochloric acid). AEP now indicates that stack number 1 emits between 2,834 and 14,662 lb/day of H_2SO_4; and that stack number 2 emits between 2,714 and 17,184 lb/day. Thus, the combined total estimated H_2SO_4 emissions, per day, from Amos equal 5,548 to 31,846 lb/day. Respectively, those equal approximately 231 to 1,327 lb/hr.

Regardless of the actual amount of sulfuric acid emitted daily or hourly from the plant, given the DAQ and newly revised AEP estimates of sulfuric acid from the plant, as well as the general mechanics of the blue-plume phenomenon, the DEP contends that the Amos plant contributed significantly to visibility impairment on January 25.

The following support that contention:

- While the sulfuric acid emitted from the Amos plant as currently configured is vapor, which has no optical properties, DAQ believes that on January 25 atmospheric conditions, at some distance from the plant, transformed the vapor into an aerosol, which refracts or reflects the blue part of the visible light spectrum.

- On January 25, air temperature at the altitude of the Amos plant combined exhaust would have approximated the NWS-recorded air temperatures at Yeager Airport. At 11:54 a.m. January 25 at Yeager, the air temperature was 21.9^{o}F; at 12:54 p.m., it was 24.1^{o}F. Over the next eight hours, the air temperature varied from 25^{o}F to a high of 27^{o}F and then dropped to 21^{o}F.

- The temperature of the exhaust gases from the Amos plant boilers typically averages approximately 300^{o}F.

- Even with dilution of the exhaust gases from the boilers with the cooling tower plumes and general dilution in the atmosphere, at some point downwind of the

Amos plant, the sudden temperature change from the approximate 300°F of the exhaust gas to that of sub-freezing ambient air temperatures thermally shocked the vapor.

- The thermal shock created an acid mist or aerosol that refracted or reflected the blue part of the visible spectrum of light.

- The continuous discharge of the Amos plant's exhaust gases in the Kanawha River Valley's atmosphere beneath the inversion layer, combined with light winds in the Kanawha River Valley, as well as the urban-haze-hood conceptual airflow patterns, to create a situation in which the mist was being fed regularly into the mixing basin formed between the Amos plant and downtown Charleston, bounded on either side by the valley walls and capped by the thermal inversion layer.

The DEP notes that on any day, including January 25, the concentration of the sulfuric acid emitted from the plant would likely and substantially be diluted in the atmosphere. However, below the inversion layer, very little volume of fresh ambient air existed to dilute the emissions.

In making its conclusion that on January 25 the Amos plant played a major role in the creation and prolongation of the blue haze, DAQ also considered other things that have already been discussed in this report: observations made by DEP staff in aerial reconnaissances; photographs by a DAQ engineer-photographer in one of those reconnaissances; video-tape of the haze cloud moving upriver from the general direction of the Amos plant; and the visibility impairment probably caused by the sulfuric acid emissions that converted from vapor to mist or aerosol.

3.7. Odor

What remains the most common, recorded odor complaint received January 25 by DEP was of a chlorine-like smell, such as bleach.

Those comments came from as far upriver as the Capitol—an observation made by the DAQ field engineer who spent approximately three hours traveling by vehicle up and down the Kanawha River Valley, from the Capitol to the Amos Plant and back, to find the source of the odor—to Institute, where a complainant described a "strong chlorine odor," and even approximately two miles west of the Amos plant, by the same DAQ field engineer just mentioned.

In between these upriver and downriver boundaries, a chlorine-like odor was noted in various locations:

- a downtown building on Hale St.
- on the property of a North Charleston residence
- at the residence of a DEP staff member who was at home sick on Montrose Ave. in South Charleston
- on the parking lot of a grocery store in Dunbar, an observation made by another DAQ staff member
- in the South Ridge area, observations made by two DEP staff, one of whom is a DAQ engineer

In fact, just minutes before leaving his home in the South Charleston hills for South Ridge Center, that DAQ engineer smelled chlorinated compounds on the property of his home. He described them as having the smell of agricultural chemicals; such as, pesticides.

It is possible that the Amos plant also played some role in this part of the episode. Twice weekly, including on Thursdays, plant personnel pour 2,000 gallons of 12.5-percent chlorine bleach in the plant's cooling towers. The chemical is used an algicide.

Other potential chlorine-like-odor contributors include Bayer CropScience in Institute; Clearon Corporation in South Charleston; and Dow/Union Carbide in South Charleston. Table 3-1 lists these sources as overall major emitters in the portion of the Kanawha River Valley from Charleston to the Amos plant.

However, the DEP acknowledges and emphasizes that, to its knowledge, none of these facilities listed, nor any other stationary source of air pollution in the Kanawha River Valley on January 25 reported any accidental spill or release of chlorine or chlorinated compounds, or any other chemicals.

The DEP also notes that, to its knowledge, no active or potential mobile source of air pollution in the Kanawha River Valley on January 25 reported an accidental spill or release of chlorine or chlorinated compounds, or any other chemical.

Thus, unlike its assessment of the blue haze, the DEP continues to be unsure of what caused and/or contributed to the odor. Simply, no information from any credible source has allowed DAQ to assign responsibility to any stationary facility or facilities and/or mobile source or sources.

APPENDIX A

Summary of 2006 Emissions Inventory
for Kanawha and Putnam Counties
for All Major Stationary Sources/Facilities Emitting Air Pollutants

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Table A-1.

Sum of Estimated Individual Facility Emissions, in Lb/hr,
For All Major Stationary Facilities in Kanawha and Putnam Counties
Ranked from Highest to Lowest Combined Rate
[Source: 2006 Emissions Inventory and Data Supplied by AEP]

Facility	Total Estimated Emission Rate for All Pollutants Combined, Lb/hr
AEP / John Amos Power Plant	44,125
AEP / Kanawha River Power Plant	4,489
Bayer CropScience	1,858
City of Charleston Sanitary Landfill	941
Disposal Service Inc. Sanitary Landfill	861
Dominion / Cornwell Compressor Station	783
E.I. du Pont de Nemours & Co.	765
Lanham Compressor Station	503
Dow/Union Carbide Corp., So. Chas. Facility	489
Clendenin 4C1200 Compressor Station	390
Dow/Union Carbide Corp., Institute	197
Coco 4C 1150 Compressor Station	106
Thomas Memorial Hospital	61
Bayer Material Science.	54
Heizer Compressor Station	49
Staten Run Compressor Station	49
Horsemill Compressor Station	32
Clearon Corp.	31
Dow/Union Carbide Corp., So. Chas. Tech Center	28
Walgrove Compressor Station	26
Toyota Motor Manufacturing West Virginia Inc.	25
Praxair Hyco Plant	19
Hunt 4C1100 Compressor Station	10
Charleston Area Medical Center, General Division	6
Carbon Compressor Station.	1

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Table A-2.
Estimated Total Emissions and Selected Pollutants, in Lb/hr, for All Major Air-Pollution Stationary Sources / Facilities in Kanawha and Putnam Counties
[Source: 2006 Emissions Inventory and Data Supplied by AEP]

Plant	SO_2	NO_X	PM	HCl	H_2SO_4	VOCs	Cl_2	Sum of All Pollutants
AEP / John E. Amos Plant	28,732.228	8,314.943	503.875	3,278.000	1,327.000	56.216	0.000	44,125
AEP / Kanawha River Plant	3,121.995	891.982	56.329	205.479	0.000	5.712	0.000	4,489
Bayer CropScience	947.185	781.953	17.935	31.387	0.000	27.557	0.030	1,858
Bayer MaterialScience, So. Chas.	0.000	0.865	0.005	0.002	0.000	51.019	0.002	54
Charleston Area Medical Center - General Division	0.852	2.866	0.284	0.434	0.000	0.124	0.000	6
Carbon Compressor Station	0.000	0.049	0.004	0.000	0.000	0.783	0.000	1
City of Charleston Sanitary Landfill	0.039	0.000	11.925	0.073	0.000	1.797	0.000	941
Clearon Corp.	0.164	19.119	7.324	0.000	0.000	0.213	1.233	31
Clendenin 4C1200 Compressor Station	0.050	246.409	0.047	0.000	0.000	7.827	0.000	390
Coco 4C1150 Compressor Station	0.015	57.187	0.787	0.000	0.000	2.949	0.000	106
Disposal Service Inc. Sanitary Landfill	0.000	0.000	12.532	0.000	0.000	1.671	0.000	861
Dominion / Cornwell Compressor Station	0.186	358.823	1.376	0.000	0.000	94.911	0.000	783
Dow / Union Carbide Corp., Institute	0.358	7.169	1.384	0.000	0.000	162.929	0.000	197
Dow / Union Carbide Corp., So. Chas. Tech Center	0.025	0.648	0.115	0.001	0.000	20.503	0.000	28
Dow / Union Carbide Corp., So. Chas. Facility	236.767	135.724	20.138	9.229	0.000	34.146	0.000	489
E.I. du Pont de Nemours & Co.	232.835	111.588	3.124	0.342	0.000	142.986	0.534	765
Hiezer Compressor Station	0.002	12.150	0.170	0.000	0.000	10.618	0.000	49
Horsemill Compressor Station	0.003	15.701	0.214	0.000	0.000	6.220	0.000	32
Hunt 4C1160 Compressor Station	0.001	5.399	0.071	0.000	0.000	0.309	0.000	10
Lanham 4C4590 Compressor Station	0.120	256.088	2.110	0.000	0.000	9.450	0.000	503
Praxair Hyco Plant	0.008	6.879	0.027	0.000	0.000	0.064	0.000	19
Staten Run Compressor Station	0.005	12.019	0.244	0.000	0.000	7.647	0.000	49
Thomas Memorial Hospital	2.125	32.759	5.525	0.008	0.000	2.575	0.006	61
Toyota Motor Manufacturing West Virginia Inc.	0.004	0.697	0.185	0.000	0.000	24.151	0.000	25
Walgrove 4C1140 Compressor Station	0.003	16.124	0.171	0.000	0.000	0.578	0.000	26
Totals	33,275	11,287	646	3,525	1,327	673	2	55,898

Notes:
SO_2 = sulfur dioxide
NO_X = nitrogen oxides
PM = particulate matter
HCl = hydrochloric acid
H_2SO_4 = sulfuric acid
Cl_2 = chlorine

Note also: Except as noted below for AEP, the Sum of All Pollutants is from the 2006 emissions inventory for each facility. The sum includes all pollutants submitted on the inventory, regardless of the amount.

Note also: The *Totals* are rounded to the nearest whole number.

Note also: The H_2SO_4 and HCl values for AEP / John Amos are from a March 2008 submittal to EPA Region III. These values were not part of the 2006 emissions inventory. No corresponding information was available for the AEP / Kanawha River Plant.

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APPENDIX B

Data, Tables and Background Regarding DAQ Estimation of Sulfuric Acid Emissions From John Amos Power Plant

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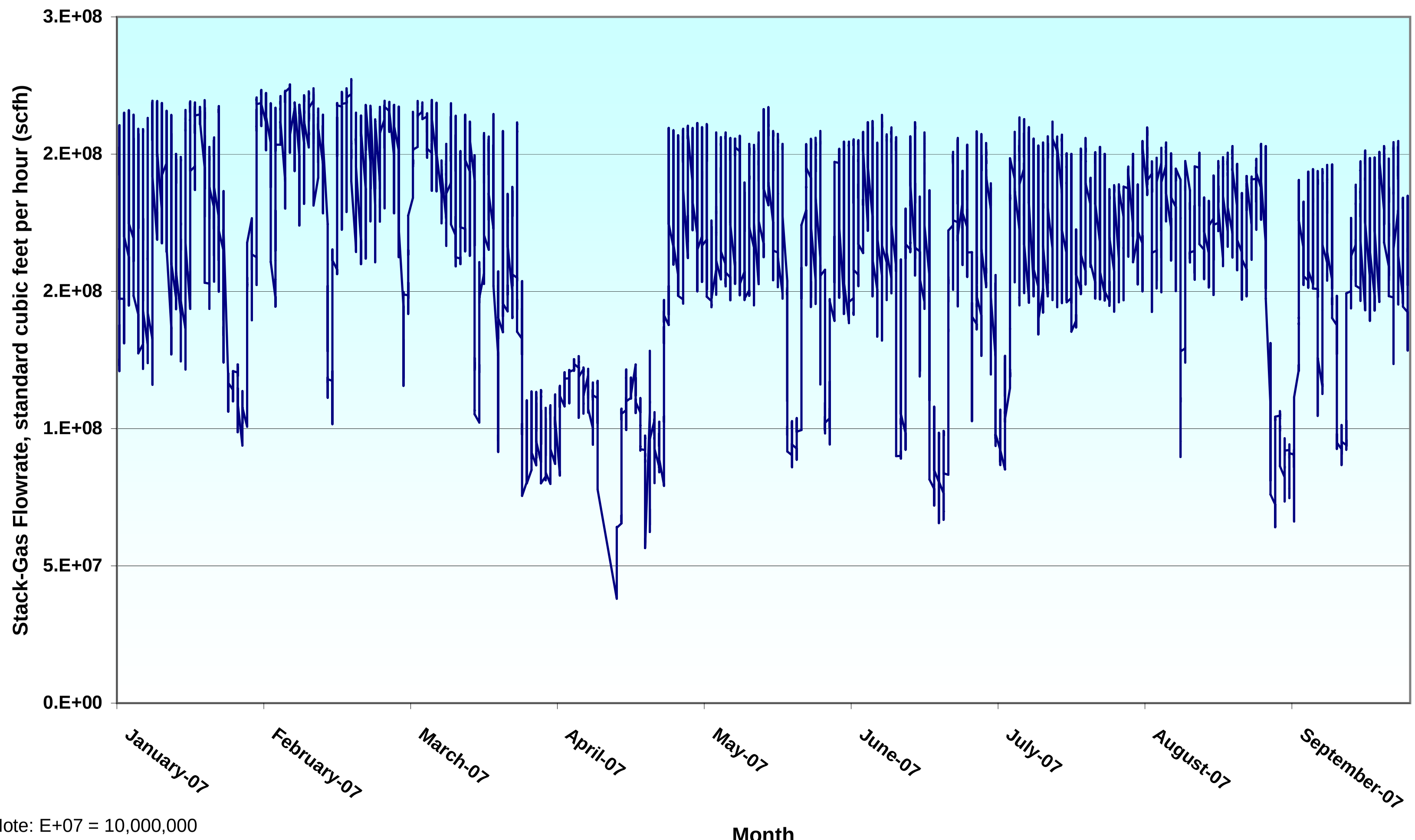
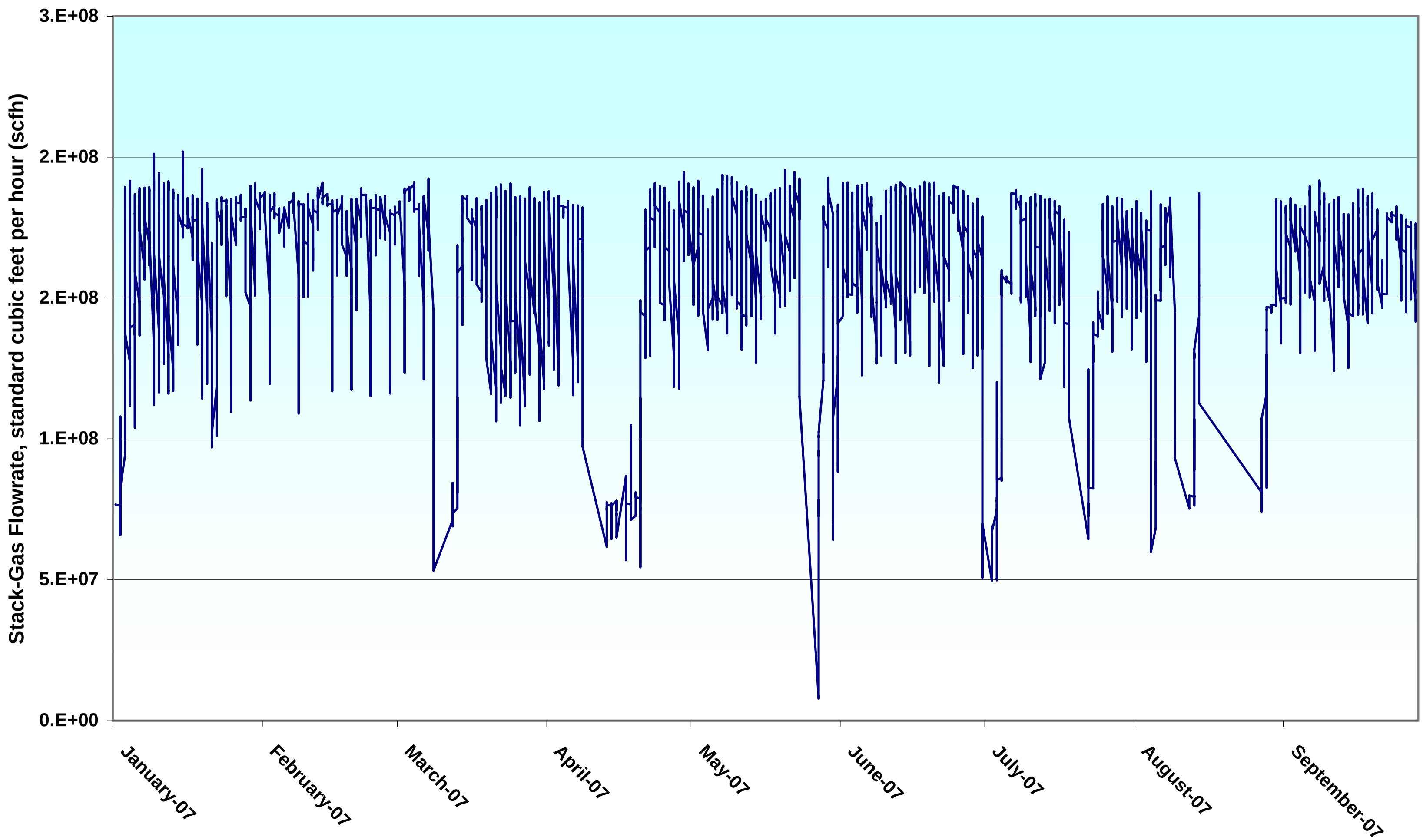
Fig. B-1. Adjusted Esimated Hourly Stack-Gas Flowrate from Stack 1--for Units 1 and 2--at John Amos Power Plant Jan.-Sept. 2007 [Source: U.S. Environmental Protection Agency Clean Air Markets Division]



Note: E+07 = 10,000,000
E+08 = 100,000,000

Fig. B-2. Adjusted Estimated Hourly Stack-Gas Flowrate from Stack 2--for Unit 3--at John Amos Power Plant: Jan.-Sept. 2007 [Source: U.S. Enviornmental Protection Agency Clean Air Market Division]



Notes: E+07 = 10,000,000
E+08 = 100,000,000

Table B-1.
Estimated H_2SO_4 Emissions, Lb/hr, from Stack 1 (for Units 1 and 2) at John Amos Power Plant
[Basis: Calendar Year 2007 Maximum Reported Exhaust Gas Flowrate and CO_2 Concentration; and Other Data from AEP]

Given:	SO_3 Flue-gas Concentration (ppm)	Flue-gas Temperature (°F)	Density of Air (lb/scf)	Flue-gas Flowrate (dscf/hr)	Flue-gas Flowrate (dscf/min)	MW H_2SO_4	MW Flue Gas
	7.9	300	0.0749	227,000,000	3,783,333	98.08	30.43
Given:	Flue-gas Composition	Fraction	Molecular Weight (MW)	MW Fraction		Element	MW
	N_2	0.790	28.02	22.1		O	16.00
	O_2	0.079	32	2.5		N	14.01
	CO_2	0.131	44.01	5.8		H	1.01
	Totals	1.000	--	30.4		S	32.06
						C	12.01
Given:	Fraction X = SO_3-to-H_2SO_4 Conversion						
	0.15						
	H_2SO_4 Emission Rate	At 100% H_2SO_4 Conversion	At Fraction X H_2SO_4 Conversion				
	lb/hr	301	45				
	tons/hr	0	0				
	lb/day	7,219	1,083				
	tons/day	4	1				
	lb/year	2,636,621	395,493				
	tons/year	1,318	198				

Notes: SO_3 concentration supplied to DAQ by American Electric Power Co., which operates the Amos plant.
In some cases, values have been rounded to the nearest whole number, or one to three places to the right of the decimal.
ppm = parts per million
^oF = degrees Fahrenheit
scf = standard cubic foot of exhaust gas at 68^{o}F and 14.696 pounds per square inch
dscf = dry standard cubic foot of exhaust gas
lb = pound
hr = hour
MW = molecular weight
N_2, O_2, CO_2, H, S and C = nitrogen, oxygen, carbon dioxide, hydrogen, sulfur and carbon, respectively
H_2SO_4 = sulfuric acid

Table B-2.

Estimated H_2SO_4 Emissions, Lb/hr, from Stack 2 (for Unit 3) at John Amos Power Plant

[Basis: Calendar Year 2007 Maximum Reported Exhaust Gas Flowrate and CO_2 Concentration; and Other Data from AEP]

Given:	SO_3 Flue-gas Concentration (ppm)	Flue-gas Temperature (°F)	Density of Air (lb/scf)	Flue-gas Flowrate (dscf/hr)	Flue-gas Flowrate (dscf/min)	MW H_2SO_4	MW Flue Gas
	12.6	300	0.0749	201,000,000	3,350,000	98.08	30.31
Given:	Flue-gas Composition	Fraction	Molecular Weight (MW)	MW Fraction		Element	MW
	N_2	0.790	28.02	22.1		O	16.00
	O_2	0.089	32	2.8		N	14.01
	CO_2	0.121	44.01	5.3		H	1.01
	Totals	1.000	--	30.3		S	32.06
						C	12.01
Given:	Fraction X = SO_3-to-H_2SO_4 Conversion						
	0.15						
	H_2SO_4 Emission Rate	At 100% H_2SO_4 Conversion	At Fraction X H_2SO_4 Conversion				
	lb/hr	426	64				
	tons/hr	0	0				
	lb/day	10,235	1,535				
	tons/day	5	1				
	lb/year	3,738,341	560,751				
	tons/year	1,869	280				

Notes: SO_3 concentration supplied to DAQ by American Electric Power Co., which operates the Amos plant.
In some cases, values have been rounded to the nearest whole number, or one to three places to the right of the decimal.
ppm = parts per million
^oF = degrees Fahrenheit
scf = standard cubic foot of exhaust gas at 68^oF and 14.696 pounds per square inch
dscf = dry standard cubic foot of exhaust gas
lb = pound
hr = hour
MW = molecular weight
N_2, O_2, CO_2, H, S and C = nitrogen, oxygen, carbon dioxide, hydrogen, sulfur and carbon, respectively
H_2SO_4 = sulfuric acid

Division of Air Quality

Memo

To: John Benedict, File

From: Todd Shrewsbury

CC: Earl Billingsley, Jesse Adkins, Renu Chakrabarty

Date: 2/15/2008

Re: Estimate of John Amos Power Plant H_2SO_4 Emissions from SO_3 Conversion

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This spreadsheet exercise was conducted in response to questions concerning quantitative emissions of sulfuric acid (H_2SO_4) from Appalachian Power Company's John Amos Power Station (079-00006) located near Poca, Putnam County, WV. Calculations were performed by assuming sulfur trioxide (SO_3) emissions reacted with moisture (H_2O) within the flues and ambient atmosphere to form H_2SO_4. This spreadsheet exercise was a joint effort of Renu Chakrabarty, Earl Billingsley, and the author.

Data Sources

Flue gas SO_3 concentrations are estimates supplied by American Electric Power (AEP), Appalachian Power's parent company (see attachments). These concentrations have the greatest affect upon the final calculated value, as H_2SO_4 emissions are directly proportional to this value. AEP documents show that SO_3 formation has two origins: combustion within the furnace, and catalytic oxidation with excess atmospheric oxygen (O_2) on the surface of the SCR catalysts. AEP shows that approximately 56% of the SO_3 is formed within the boiler and 44% within the SCR's. Flue gas flows and carbon dioxide (CO_2) concentrations were obtained from the Electronic Data Reports (EDR's) submitted by the company to EPA's Clean Air Markets Division (CAMD) in support of the Acid Rain Program. EDR's are available for download from CAMD's website and can be viewed with EPA's Monitoring Data Checking Software (MDC). This was the source of CO_2 diluent and flue flow data (see attached graphs [APPENDIX C, Figs. 1 and 2]), which was varied to best simulate actual conditions. Quarters 1 through 3 of 2007 data were reviewed for the maximum values used in the calculations. Flue temperature and air density were best guess assumptions and these are easily changed within the spreadsheet, although these values do not significantly affect the calculation when varied within reasonable expected ranges.

Calculations

The attached tables [APPENDIX C, Tables C-1 and C-2] summarize the calculated emissions at the specified conditions. Heading cells utilize a blue field background. Initial condition entry values are characterized by a yellow field color. A light green field denotes an intermediate calculated value used to support the final results. Final results are colored within gold fields. All four tables list H_2SO_4 emissions in both pound and ton rates on an hourly, daily, and annual basis.

Table 1 [APPENDIX C, Table C-1] calculates the amount of H_2SO_4 emitted from the Units 1 & 2 common stack, assuming 100% conversion of SO_3 to H_2SO_4. Initial parameters chosen are maximum flue gas and maximum CO_2 diluent values from the available 2007 EDR data. Also included are H_2SO_4 emissions assuming an SO_3 conversion rate of 15%, an arbitrary but reasonable conversion rate. The bottom of the table lists a summary of Table 1 and Table 2 (Unit 3) emissions at these maximum conditions. Tables 1 & 2 utilize complimentary conditions.

Table 2 [APPENDIX C, Table C-2] calculates the amount of H_2SO_4 emitted from the Unit 3 stack, assuming 100% conversion of SO_3 to H_2SO_4. Initial parameters chosen are maximum flue gas and maximum CO_2 diluent values from the available 2007 EDR data. Also included are H_2SO_4 emissions assuming an SO_3 conversion rate of 15%. The bottom of the table lists a summary of Table 1 (Units 1 & 2) and Table 2 emissions at these maximum conditions. Tables 1 & 2 utilize complimentary conditions.

Table 3 calculates the amount of H_2SO_4 emitted from the Units 1 & 2 common stack, assuming 100% conversion of SO_3 to H_2SO_4. Initial CO_2 diluent and flue flow parameters chosen reflect values taken from the available 2007 EDR data that most closely matched the average unit gross load data made available to DAQ in a spreadsheet from AEP's Nikki Coalter. Coalter's spreadsheet detailed the period from January 24, 2008 at 13:00 until January 26, 2008 at 12:00, which covers the period of the blue haze incident. Also included are H_2SO_4 emissions assuming an SO_3 conversion rate of 15%. The bottom of the table lists a summary of Table 3 and Table 4 (Unit 3) emissions at these selected conditions. Tables 3 & 4 utilize complimentary conditions.

Table 4 calculates the amount of H_2SO_4 emitted from the Unit 3 stack, assuming 100% conversion of SO_3 to H_2SO_4. Initial CO_2 diluent and flue flow parameters chosen reflect values taken from the available 2007 EDR data that most closely matched the average unit gross load data made available to DAQ in a spreadsheet from AEP's Nikki Coalter. Coalter's spreadsheet detailed the period from January 24, 2008 at 13:00 until January 26, 2008 at 12:00, which covers the period of the blue haze incident. Also included are H_2SO_4 emissions assuming an SO_3 conversion rate of 15%. The bottom of the table lists a summary of Table 3 (Units 1 & 2) and Table 4 emissions at these selected conditions. Tables 3 & 4 utilize complimentary conditions.

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APPENDIX C

January 2008 Ambient-Air-Quality Monitoring Data from the South Charleston and Guthrie Agricultural Center Sites for Speciated Particulate Matter ($PM_{2.5}$, Sulfates and Nitrates)

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Fig. C-1. Comparison of Atmospheric $PM_{2.5}$ Concentrations:
South Charleston, Charleston / Baptist Temple and Guthrie Agricultural Station, January 2008

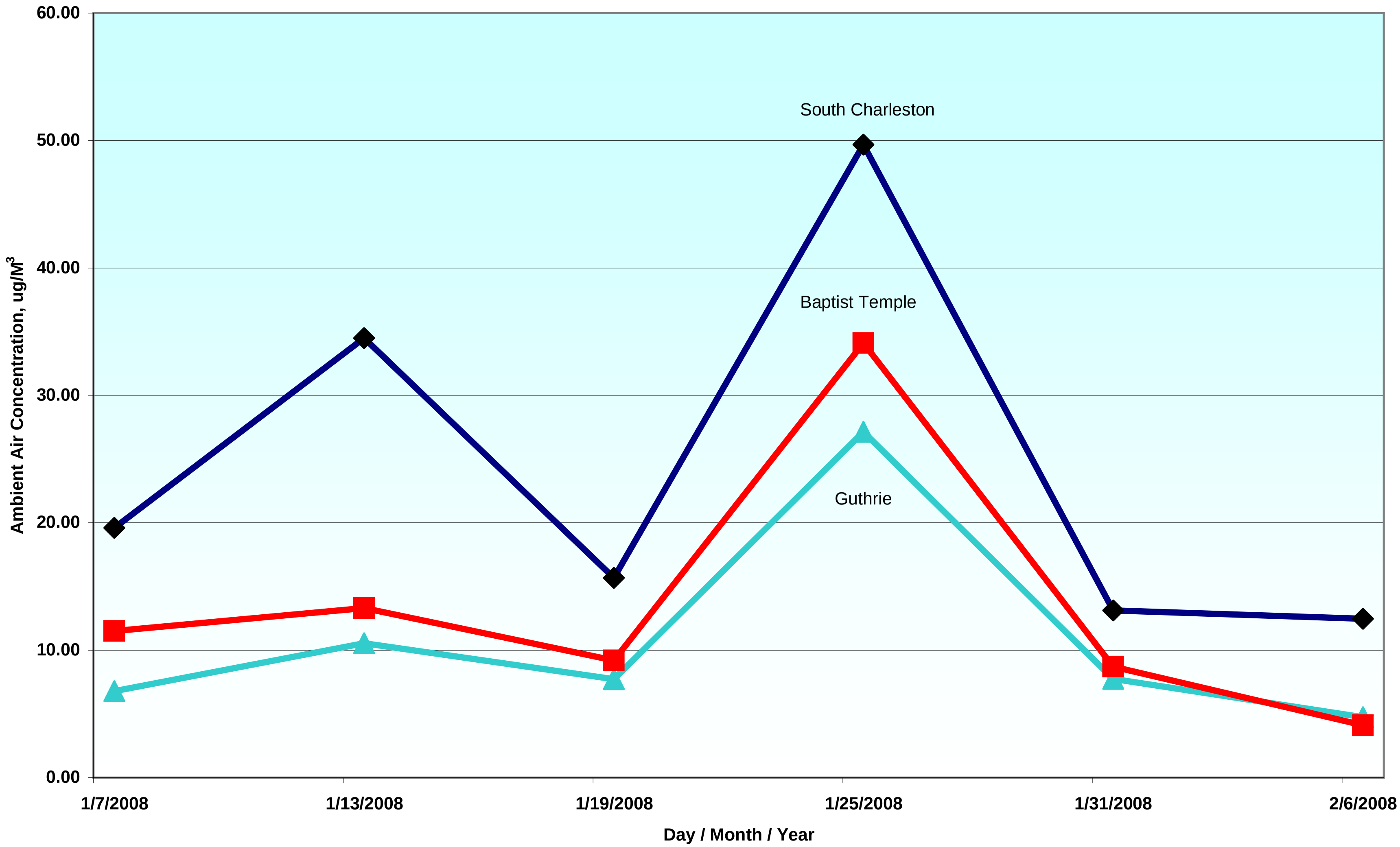


Fig. C-2. $PM_{2.5}$, Sulfates and Nitrates Ambient Air Concentrations: South Charleston, Jan. 2008

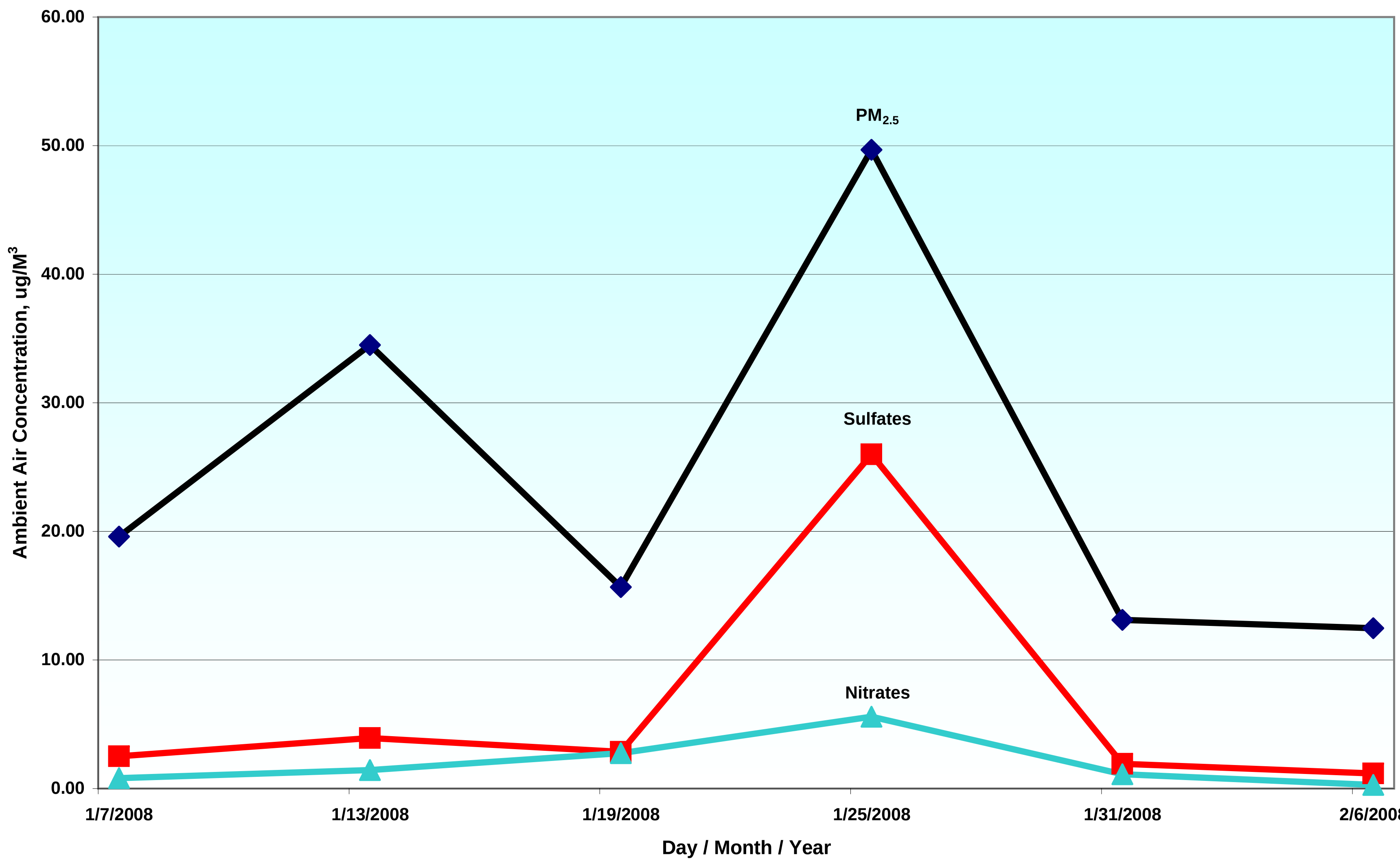
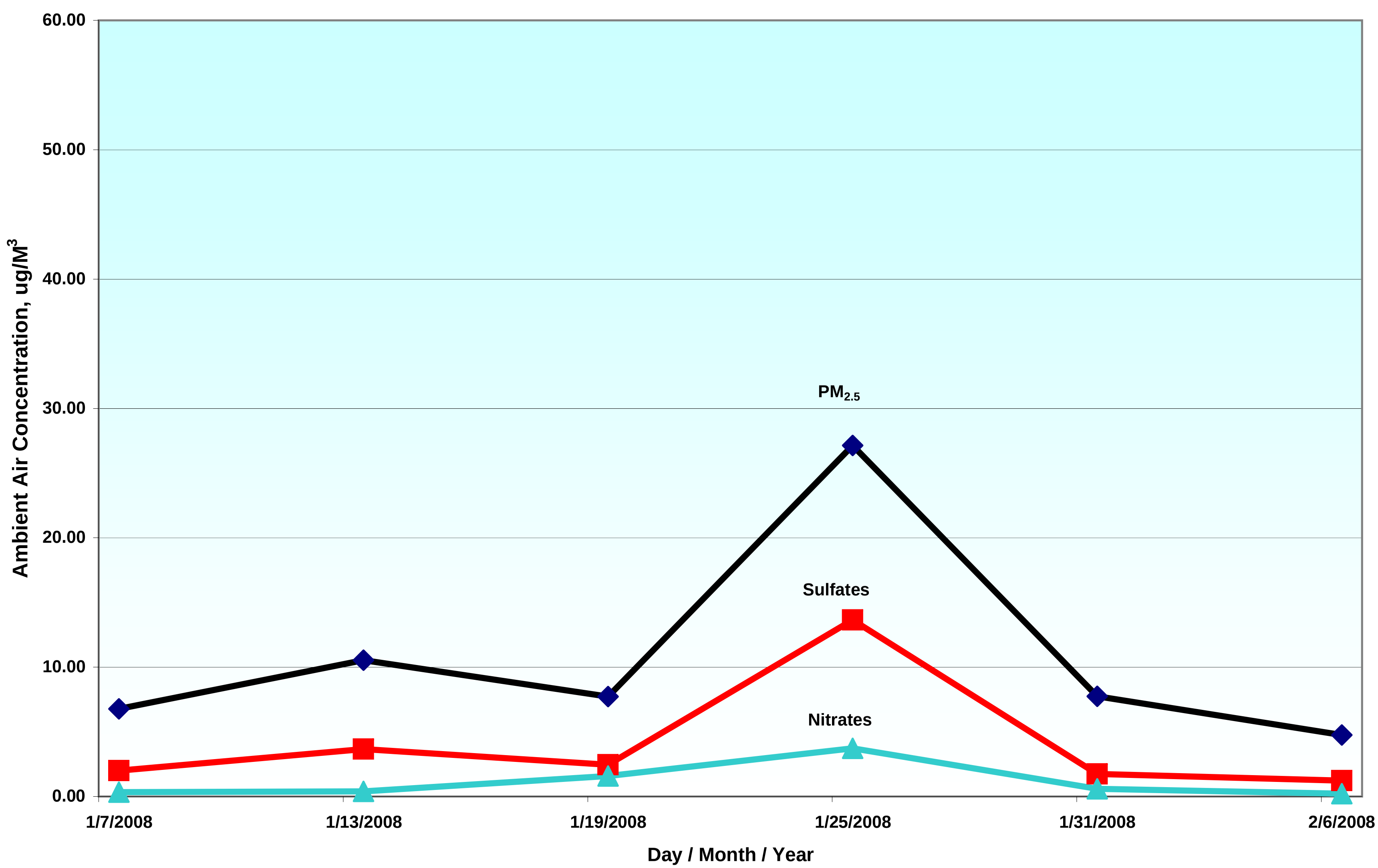


Fig. C-3. $PM_{2.5}$, Sulfates and Nitrates Ambient Air Concentrations: Guthrie, Jan. 2008



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