United States
Environmental Protection
Agency

Air Pollution Training Institute
MD 20
Environmental Research Center
Research Triangle Park, NC 27711

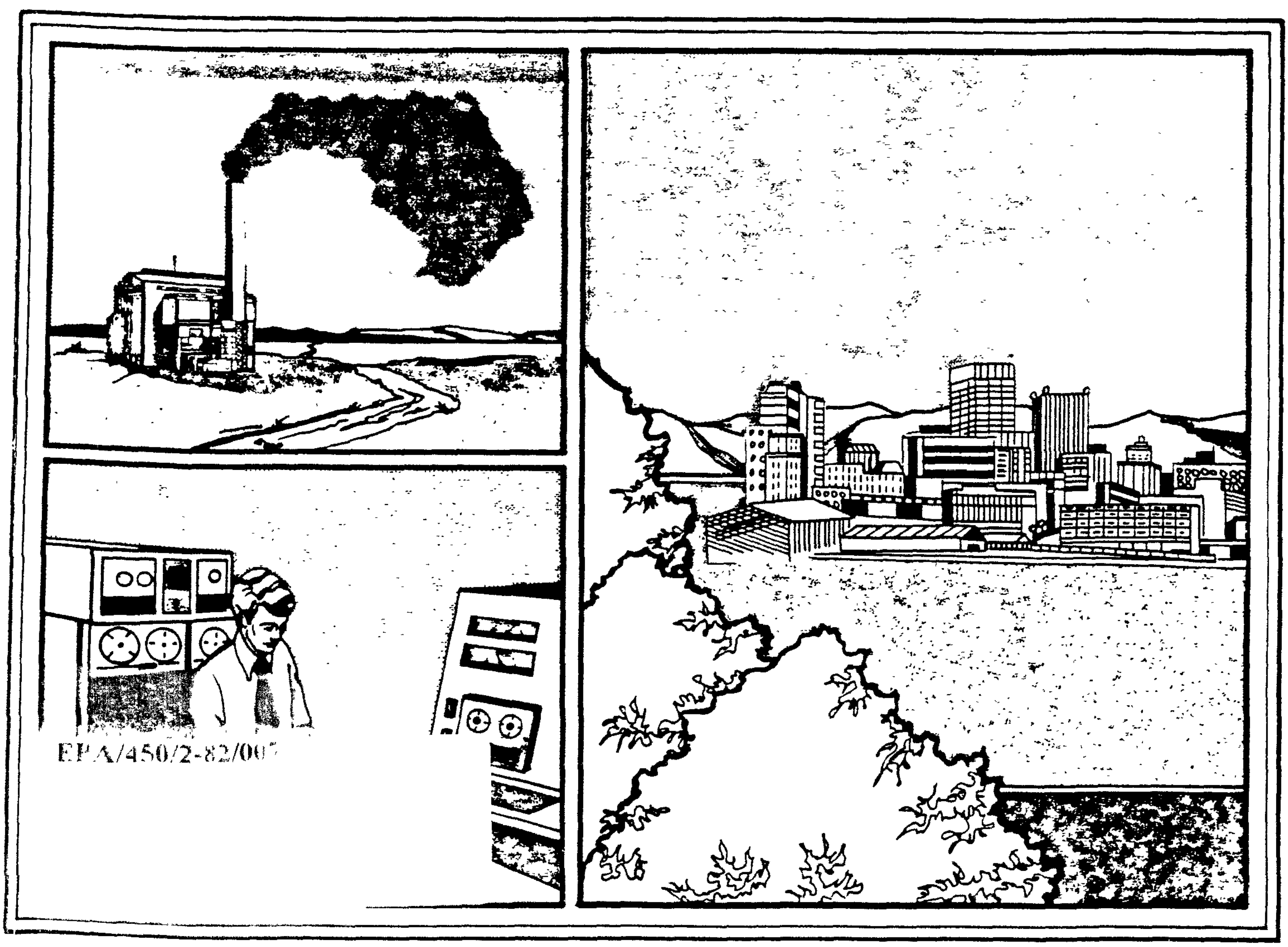
EPA 450/2-82-007
March, 1983

Air

EPA

APTI
Course SI:410
Introduction to Dispersion Modeling

Self-instructional Guidebook



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Introduction to Dispersion Modeling

Self-instructional Guidebook

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Under Contract No.
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EPA Project Officer
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United States Environmental Protection Agency
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
Research Triangle Park, NC 27711

Notice

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Unit 1
Introduction to Course Materials

Course Description
Course Goal and Objectives
Requirements for Successful Completion of this Course
Materials
Using the Guidebook
Instructions for Completing the Final Examination

Course Description

This training course is a 35½-hour self-instructional course using slide/tape presentations, text materials, and reading assignments dealing with dispersion models for industrial point sources. Models and their use in determining air pollution impact areas, such as the urban area in Figure 5-1, and ground-level concentrations will be examined in two case studies. Course topics include the following:

- Introduction to the regulations requiring air quality model use
- Introduction to air quality models for industrial point sources
- General characteristics of air quality models for industrial point sources
- Review of UNAMAP, Version 4 models*
- Input data required for specific models
- Interpreting the output data from specific models
- Case studies

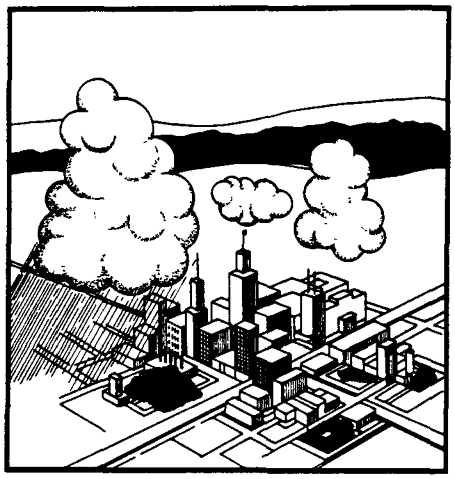


Figure 1-1. Dispersion modeling concerns.

Course Goal and Objectives

Goal

The purpose of this course is to familiarize you with the general concepts and specific data requirements of air quality models for industrial point sources for you to use to make competent decisions about the impact of air pollution on air quality.

Objectives

Upon completing this course, you should be able to:

1. cite the specific parts of the Federal regulations that require the modeling of air pollution concentrations.
2. name and describe the original air quality modeling technique used in formulating State Implementation Plans (SIPs).
3. describe one typical atmospheric pollution problem that can be solved using air quality modeling.
4. describe the basic Gaussian approach for an atmospheric dispersion model for industrial point sources.

*Version 5 is scheduled for release in 1983 and will add several new models to UNAMAP. All of the models discussed in this course will remain unchanged with the release of Version 5.

5. explain the rationale for using the Gaussian distribution in atmospheric dispersion models for industrial point sources.
6. list the atmospheric models for industrial point sources that are available on UNAMAP, Version 4.
7. list the limitations of Gaussian-based atmospheric dispersion models for industrial point sources.
8. describe the method of obtaining model input data for industrial point sources.
9. explain typical input data for an atmospheric dispersion model for industrial point sources.
10. choose the specific section of a given model's output data that computes ground-level concentrations.

Requirements for Successful Completion of this Course

In order to receive 3.5 Continuing Education Units (CEUs) and a certificate of course completion, you must:

1. take a mail-in final examination.
2. achieve a final exam grade of at least 70%.

Materials

Additional Required Reading

EPA 450/2-78-027, *Guideline on Air Quality Models,* April 1978.

Audiovisual

Slide/tape presentations:

- SI:410-1 *Introduction to Air Quality Regulations*
- SI:410-2 *Introduction to Air Quality Modeling*
- SI:410-3 *Air Quality Modeling Summary*

Supplementary

EPA 450/4-77-001, *Guidelines for Air Quality Maintenance Planning and Analysis, Volume 10 (Revised), Procedures for Evaluating Air Quality Impact of New Stationary Sources,* October 1977.

NASA SP-322, *A Review of Methods for Predicting Air Pollution Dispersion,* 1973.

EPRI EA-1131, *Appendix D: Available Air Quality Models,* Electric Power Research Institute, Palo Alto, CA, August 1979.

DOE/TIC-11223, *Handbook on Atmospheric Diffusion*, U.S. Department of Energy, 1982.

45 *Federal Register* 52676, "Requirements for Preparation, Adoption, and Submittal of Implementation Plans; Approval and Promulgation of Implementation Plans," August 7, 1980.

Using the Guidebook

This guidebook directs your progress through the slide/tape presentations, text material, and reading assignments. It contains seven units consisting of reading, supplementary, and audiovisual materials. The first unit introduces the course. The second unit, containing three lessons, has two slide/tape presentations and a reading assignment that will give an overview of air quality regulations and air quality models. The next four units will be self-paced, presented as text with review questions. The last unit briefly summarizes the major points of the course in a slide/tape presentation.

Completing the Review Exercises

Complete the review exercise for each lesson upon completing the reading assignments and slide/tape presentations for that lesson. If you answered any review exercise incorrectly, review the reading assignment and/or slide/tape script. Then proceed to the next lesson in the guidebook.

To complete a review exercise, place a piece of paper across the page covering the questions below the one you are answering. After answering the question, slide the paper down to uncover the next question. The answer for the first question will be given on the right side of the page separated by a line from the second question (Figure 1-2). All answers to review questions will appear below and to the right of their respective questions. The answers will be numbered to match the questions.

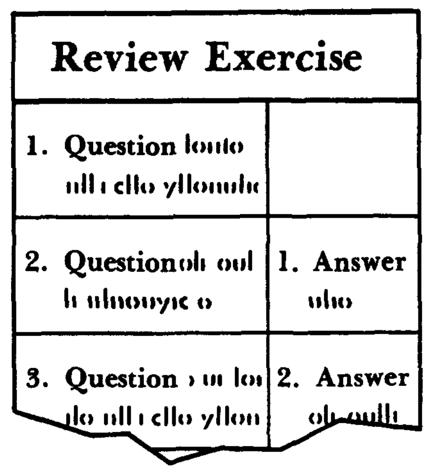


Figure 1-2. Review exercise format.

Using the Slide/Tapes

The audiocassettes and slide sets have been numbered consecutively. Table 1-1 lists tape number, slide series numbers, and appropriate lesson number. The script for each presentation can be found in the unit and lesson number listed.

You do not need to follow the script provided in the appropriate lesson as you view each slide/tape presentation. The script is provided for you to use to review the content.

The audiocassettes provided with the course materials will most likely have an audible slide change tone. Begin the tape

Table 1-1. Cross-listing of slide/tape presentations with unit and lesson numbers.

Slide/tape audio cassette number	Slide numbers	Unit number	Lesson number
1	1-1 through 1-35	2	1
2	2-1 through 2-34	2	2
3	3-1 through 3-18	7	—

with the first slide showing and then advance the slides manually as you hear each tone.

If you have requested audiocassettes with inaudible tones that automatically advance the slides, begin the tape with the first slide showing. Should you need to use these tapes for manual advance, consult the scripts for slide change points.

Lesson Content

- Reading assignments (if ones in addition to this guidebook are required)
- Slide/tape presentation: slide numbers and cassette number (if applicable)
- Lesson goal and objectives
- Reading guidance (if applicable)
- Text of lesson (except where readings from other documents are specified) or script from slide/tape presentations
- Review exercise and review exercise answers

If supplementary reading material is available, it will be recommended in the appropriate lesson, but it is not required for course completion.

Instructions for Completing the Final Examination

Contact the Air Pollution Training Institute if you have any questions about the course or when you are ready to receive a copy of the final examination.

After completing the final exam, return it and the answer sheet to the Air Pollution Training Institute. The final exam grade and course grade will be mailed to you.

Air Pollution Training Institute
Environmental Research Center
MD 20
Research Triangle Park, NC 27711

Unit 2
Introduction to Air Quality Regulations and Air Quality Modeling

Lesson 1
Introduction to Air Quality Regulations

Slide/Tape Presentation

First, view the slide/tape presentation—cassette no. 1 and keyed slides 1-1 through 1-35, *Introduction to Air Quality Regulations*—then complete the reading assignment.

Reading Assignment

EPA 450/2-78-027, *Guideline on Air Quality Models*, pp. 1–12.

Section 165 of the Clean Air Act Amendments of 1977, p. 2-5 of this guidebook.

Title 40, Part 51.24(l) of the *Code of Federal Regulations*, p. 2-5 of this guidebook.

National Ambient Air Quality Standards, p. 2-6 of this guidebook.

Prevention of Significant Deterioration Increments, p. 2-6 of this guidebook.

Supplementary Reading

45 *Federal Register* 52676, "Requirements for Preparation, Adoption, and Submittal of Implementation Plans; Approval and Promulgation of Implementation Plans," August 7, 1980.

Lesson Goal and Objectives

Goal

To familiarize you with the regulations that require air quality modeling and the manner in which models are required to be used in Control Strategy Evaluation, New Source Review, and Prevention of Significant Deterioration programs.

Objectives

Upon completing this lesson, you should be able to:

1. cite the specific part number of the Clean Air Act Amendments of 1977 that requires air quality modeling.
2. cite the specific section of the *Code of Federal Regulations* that requires air quality modeling be used in estimating ambient concentrations.
3. name the three regulatory programs using air quality models as specified in the *Guideline on Air Quality Models.*
4. describe the concept of the "highest, second-highest" concentrations.

Clean Air Act: Section 165. Preconstruction Requirements Requiring Use of Air Quality Models.

Sec. 165. (a) No major emitting facility on which construction is commenced after the date of enactment of this part may be constructed in any area to which this part applies unless—

(1) a permit has been issued for such proposed facility in accordance with this part setting forth emission limitations for such facility which conform to the requirements of this part;

(3) The owner or operator of such facility demonstrates that emissions from construction or operation of such facility will not cause, or contribute to, air pollution in excess of any (A) maximum allowable increase or maximum allowable concentration for any pollutant in any area to which this part applies more than one time per year, (B) national ambient air quality standard in any air quality control region, or (C) any applicable emission standard or standards of performance under this Act;

(3) The Administrator shall within six months after the date of enactment of this part promulgate regulations respecting the analysis required under this subsection which regulations—

(D) shall specify with reasonable particularity each air quality model or models to be used under specified sets of conditions for purposes of this part.

Any model or models designated under such regulations may be adjusted upon a determination, after notice and opportunity for public hearing, by the Administrator that such adjustment is necessary to take into account unique terrain or meteorological characteristics of an area potentially affected by emissions from a source applying for a permit required under this part.

Title 40, Part 51.24 of the *Code of Federal Regulations*

(1) *Air quality models.* (1) The plan (State Implementation Plan) shall provide for procedures which specify that—

(i) All estimates of ambient concentrations required under paragraph (1) shall be based on the applicable air quality models, data bases, and other requirements specified in the *Guideline on Air Quality Models* (OAQPS 1.2-080, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711, April 1978).

(ii) Where an air quality impact model specified in the *Guideline on Air Quality Models* is inappropriate, the model may be modified or another model substituted.

(iii) A substitution or modification of a model shall be subject to public comment procedures developed in accordance with paragraph (r) of this section.

(iv) Written approval of the Administrator must be obtained for any modification or substitution.

(v) Methods like those outlined in the *Workbook for the Comparison of Air Quality Models* (U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711, April 1977) should be used to determine the comparability of air quality models.

(2) The *Guideline on Air Quality Models* is incorporated by reference. On April 27, 1978, the Office of the Federal Register approved this document for incorporation by reference. A copy of the guideline is on file in the Federal Register library.

(3) The documents referenced in this paragraph are available for public inspection at EPA's Public Information Reference Unit, Room 2922, 401 M Street SW., Washington, D.C. 20460, and at the libraries of each of the ten EPA Regional Offices. Copies are available as supplies permit from the Library Service Office (MD-35), U.S. Environmental Protection Agency, Research Triangle Park, NC 27711. Also, copies may be purchased from the National Technical Information Service, 5285 Port Royal Road, Springfield, Va. 22161.

Table 2-1. National Ambient Air Quality Standards (NAAQS).

Pollutant	Averaging time	Primary standards	Secondary standards
Sulfur dioxide (SO_2)	Annual arithmetic mean	80 $\mu g/m^3$ (0.03 ppm)	– –
	24 hours	365 $\mu g/m^3$ (0.14 ppm)	– –
	3 hours	–	1300 $\mu g/m^3$ (0.5 ppm)
Total suspended particulates (TSP)	Annual geometric mean	75 $\mu g/m^3$	60 $\mu g/m^3$*
	24 hours	260 $\mu g/m^3$	150 $\mu g/m^3$
Carbon monoxide (CO)	8 hours	10 mg/m^3 (9 ppm)	Same as primary
	1 hour	40 mg/m^3 (35 ppm)	
Ozone (O_3)	1 hour	240 $\mu g/m^3$ (0.12 ppm)	Same as primary
Nitrogen dioxide (NO_2)	Annual arithmetic mean	100 $\mu g/m^3$ (0.05 ppm)	Same as primary
Lead (Pb)	3 months	1.5 $\mu g/m^3$	Same as primary

Note: National standards other than those based on annual arithmetic means or annual geometric means are not to be exceeded more than once per year. All standards are deterministic except for ozone, which is based on a statistical definition.

National primary standards: the levels of air quality necessary, with an adequate margin of safety, to protect the public health.

National secondary standards: the levels of air quality necessary to protect the public welfare from any known or anticipated adverse effects of a pollutant.

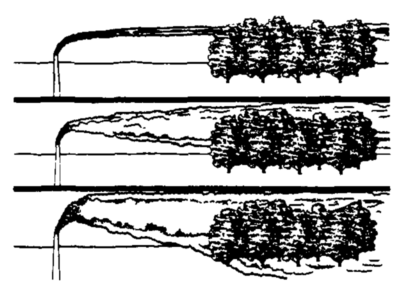
*Guideline to be used assessing implementation plans.

Table 2-2. Prevention of Significant Deterioration (PSD) increments.

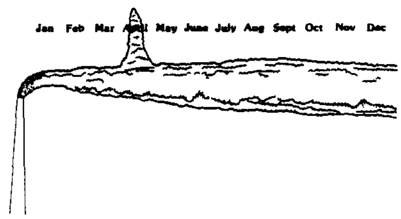
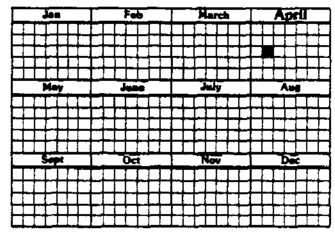
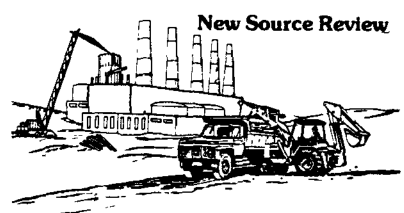
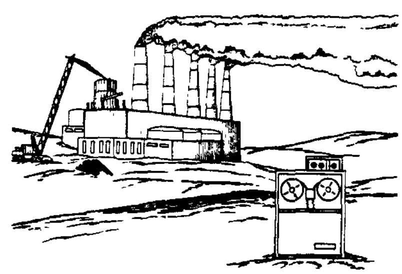
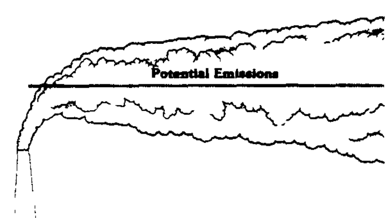
Pollutant	Maximum allowable increase ($\mu g/m^3$) Class I	II	III
Particulate matter:			
Annual geometric mean	5	19	37
24-hour maximum	10	37	75
Sulfur dioxide:			
Annual arithmetic mean	2	20	40
24-hour maximum	5	91	182
3-hour maximum	25	512	700

Note: Increments other than those based on annual means are not to be exceeded more than once per year. The full increment is not to be used if it would result in a violation of a NAAQS. Increment consumption is limited to half the maximum allowable at State borders.

Introduction to Air Quality Regulations

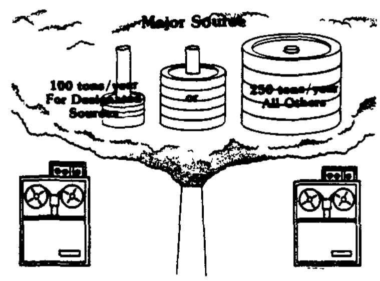
Slide no.	Script	Selected visuals*
1.	Focusing slide—no narrative	FOCUS
2.	The 1977 Clean Air Act Amendments require air quality modeling to help improve our air quality and keep pollution concentrations below certain levels.	Introduction to Air Quality Regulations
3.	An air quality model is used to determine the effect of air pollution on ambient air—that is, on the air that is around us.	
4.	The regulations that were issued call for modeling in three programs: Prevention of Significant Deterioration, New Source Review, and Control Strategy Evaluations.	• Prevention of Significant Deterioration • New Source Review • Control Strategy Evaluations
5.	The first program, Prevention of Significant Deterioration, or PSD, was designed to prevent air quality from deteriorating in areas where it is already better than required by the National Ambient Air Quality Standards. Modeling is used to verify that the air quality does not exceed these standards.	Prevention of Significant Deterioration
6.	Let's take an example. In recreational areas like national parks, wilderness areas, and other protected areas, the ambient air is to remain relatively free from industrial and other pollution sources.	
7.	If sources are in the area, the air quality may change by certain amounts over time, and this change is specified in the regulations.	
8.	These concentration increases are called PSD increments. They define the amount that pollutant concentrations can increase from a set baseline for all future time. The PSD increment system is divided into three land-use classes, based upon the amount of air quality degradation to be allowed. Class I lands, which include most wilderness areas and national parks, are protected the most.	

*Illustrations included here, no live shots included.

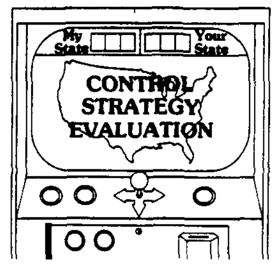
Slide no.	Script	Selected visuals
9.	For instance, for short-term periods, like 3-hour or 24-hour periods, maximum concentration increments may be exceeded only once a year.	
10.	In other words, since there are 365 days per year, the maximum 24-hour increment could be exceeded only one day in that 365-day period.	
11.	The 1977 Clean Air Act Amendments do allow a pollution source to apply for a variance through which increments may be exceeded more than once.	
12.	New Source Review is the second program for which modeling is used. New Source Review is tied to PSD and to other programs. It concerns the effects on air quality of either building new pollution sources or making certain modifications to existing sources.	
13.	When a new source of pollution is to be built, or an existing source is to be changed, modeling can be used to help predict that source's effect on air quality. However, modeling is not **always** used. A new or modified source must meet certain criteria before modeling is required.	
14.	In general, the impact on air quality of a new source only has to be modeled if it is a major source. The determination of whether a source is major or not is based on its potential emissions. Potential emissions are the emissions at maximum design capacity after the application of pollution control technology and operating restrictions.	

Slide no.	Script	Selected visuals

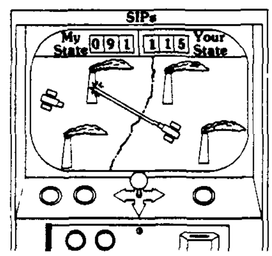
15. A major source has the potential to emit 100 tons or more per year of any pollutant regulated by the Clean Air Act for certain designated source categories, and 250 tons or more per year for all other sources. The sources in the 100-ton category include large fossil fuel-fired power plants, kraft pulp mills, smelters, steel mills, and oil refineries.



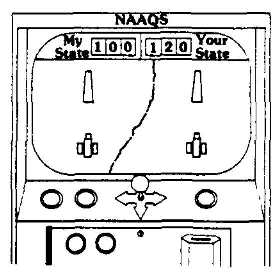
16. The third of our three programs requiring modeling is called Control Strategy Evaluation.



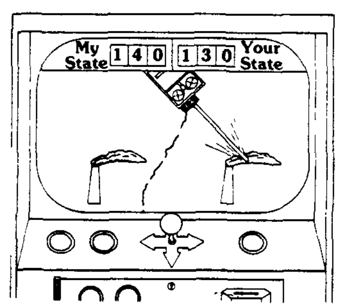
17. Individual States are required to have State Implementation Plans, or SIPs, for air pollution control. These implementation plans describe the methods by which each State intends to control air pollution within its borders.



18. These plans are designed to ensure that each State meets the National Ambient Air Quality Standards for each pollutant believed to adversely affect public health or welfare. These are known as criteria pollutants.

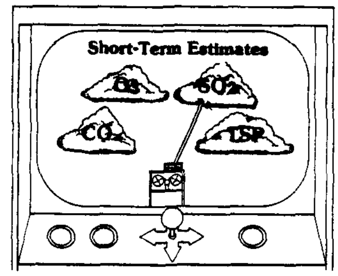


19. In order to evaluate whether or not the plans are effective, the air quality must be modeled by an air quality model that has been accepted for regulatory evaluations by the United States Environmental Protection Agency.

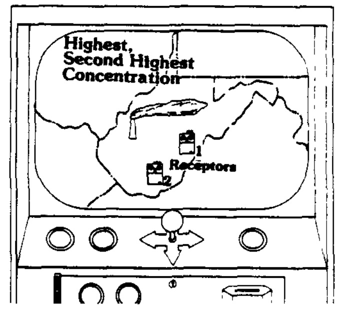


Slide no.	Script	Selected visuals

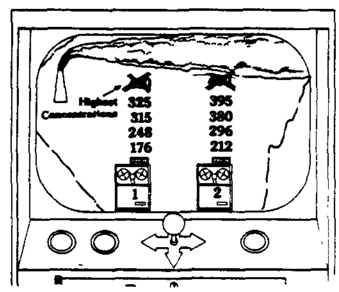
20. Short-term (24 hours or less) pollutant concentration estimates are for four criteria pollutants: ozone, sulfur dioxide, total suspended particulates, and carbon monoxide.



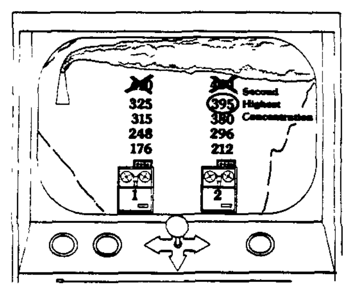
21. These estimates of air quality are based on a concept called the "highest, second-highest" concentration, which is consistent with EPA's definition of when an air quality standard is violated. That is, the short-term standard must be exceeded two or more times in a year for a violation to occur. The concept requires making air quality estimates **downwind** of a pollution source at a number of different points, called receptors.



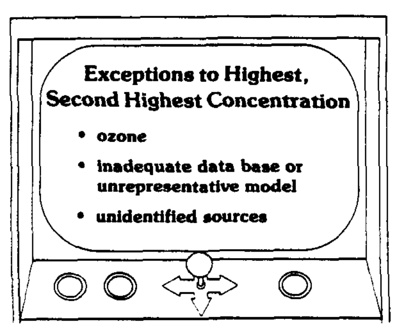
22. The pollutant concentrations determined from modeling are ranked from highest to lowest for **each** receptor site. The highest concentration from **each** receptor's data is discarded.



23. Then, the next observed single-highest concentration determined from **all** of the receptor estimates is chosen as **the** "highest, second-highest" concentration.

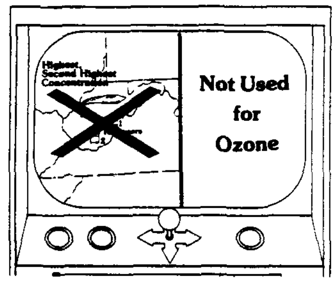


24. There are times when the "highest, second-highest" method of selecting concentrations **cannot** be used: for ozone, for an inadequate data base or unrepresentative model, and for unidentified sources.

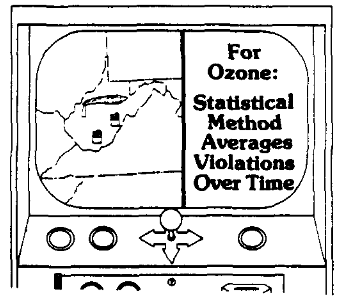


Slide no.	Script	Selected visuals

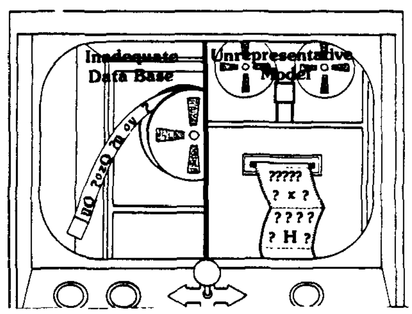
25. The first exception is ozone.



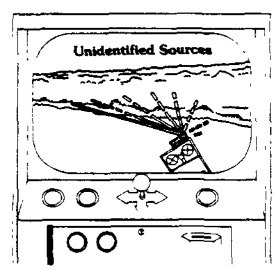
26. To determine expected violations for ozone, statistical methods are used rather than the "highest, second-highest" method.



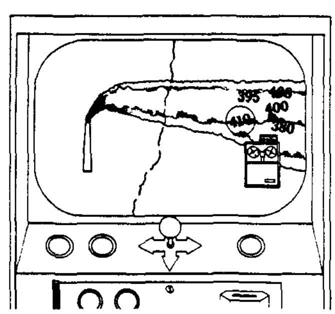
27. Another exception is when the Regional Administrator identifies an inadequate data base or an unrepresentative air quality model. An inadequate data base occurs when **not enough** data is available. An unrepresentative air quality model is one that cannot adequately simulate a particular physical situation.



28. The last exception to using the "highest, second-highest" concentration as an estimate is when maximum concentrations are caused by sources that cannot be identified. When air quality monitoring data from specific sites indicate that existing concentrations are greater than those predicted by the model, then a major source has not been identified.

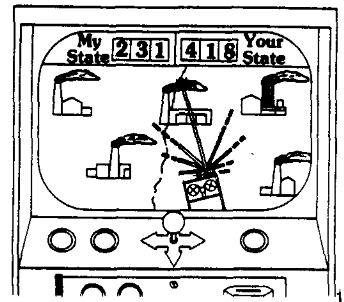


29. For example, during certain weather situations, high pollution concentrations may be transported into an area from an unknown source. When this occurs, the higher measured concentration should be used instead of the model results in specifying emission limits.



Slide no. **Script** **Selected visuals**

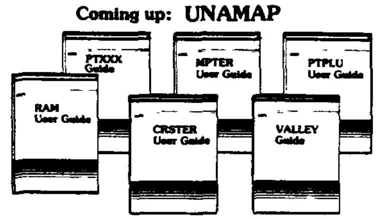
30. Therefore, determining the pollutant concentrations on which to base judgments about the air quality is not a simple matter. Many techniques have been developed to interpret information about clean air in wilderness areas, cities, and around factories.



31. In summary, the 1977 Clean Air Act Amendments require modeling to help keep the air clean. Regulations specify that three programs use modeling: Prevention of Significant Deterioration, New Source Review, and Control Strategy Evaluation.

32. In the next lesson, we will introduce air quality models. We will discuss some of the Gaussian plume point source models available on the UNAMAP Series.

Coming up: UNAMAP



33. Credit: Crew

Introduction to
Air Quality Regulations

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Graphics: Leslie White
Photography/Audio: David Churchill
Narration: Rick Palmer

34. Credit: NET/EPA Contract

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Environmental
Training

Review Exercise

1. Section ________ of the Clean Air Act Amendments of 1977 requires air quality modeling.	
2. True or False? The specific section of the Clean Air Act Amendments of 1977 that requires air quality modeling lists the air quality models that must be used.	1. 165
3. The individual who has the authority given by the Clean Air Act Amendments of 1977 to allow a modeler to adjust a specific model in case of inadequacy is the a. State health officer. b. Regional Administrator. c. Air Quality Modeler. d. Governor of the State.	2. False
4. Title _______ Part ________ of the *Code of Federal Regulations* requires the use of models to estimate concentrations needed to carry out the State Implementation Plan.	3. b. Regional Administrator.
5. Name the three programs specified in the *Guideline on Air Quality Models* that require air quality modeling.	4. 40, 51.24
6. True or False? The Prevention of Significant Deterioration means that **no** increase in air pollution concentrations will be allowed.	5. • Prevention of Significant Deterioration, • New Source Review, • Control Strategy Evaluation
7. The short-term PSD increments may be exceeded a. every 24 hours. b. once every week. c. once every hour. d. once a year.	6. False
8. For a new steel mill or oil refinery, New Source Review will require modeling if potential emissions are greater than a. 100 pounds per day. b. 1000 pounds per year. c. 100 tons per year. d. 10 tons per day.	7. d. once a year.
	8. c. 100 tons per year.

9. True or False? Potential emissions for a new source are the amount of pollutant that would be released into the air **before** the application of required control equipment.	
10. Receptors for a given area have recorded the following concentrations (in $\mu g/m^3$). Circle the **one** "highest, second-highest" concentration for this specific area. Receptor #1 / Receptor #2 / Receptor #3 387 / 297 / 311 276 / 389 / 324 401 / 392 / 356	9. False
11. True or False? There are **no** exceptions to using the method of "highest, second-highest" concentrations as air quality estimates.	10. 389 $\mu g/m^3$
12. The PSD increment for 24-hour SO_2 levels in a Class II area is a. 365 $\mu g/m^3$. b. 5 $\mu g/m^3$. c. 20 $\mu g/m^3$. d. 91 $\mu g/m^3$.	11. False
	12. d. 91 $\mu g/m^3$.

Lesson 2
Introduction to Air Quality Modeling

Slide/Tape Presentation

First, view the slide/tape presentation—cassette no. 2 and keyed slides 2-1 through 2-34, *Introduction to Air Quality Modeling*—then complete the reading assignment.

Reading Assignment

EPA 450/2-78-027, *Guideline on Air Quality Models,* pp. 13-24.

Supplementary Reading

NASA SP-322, *A Review of Methods for Predicting Air Pollution Dispersion,* pp. 1-10.

EPRI EA-1131, *Appendix D: Available Air Quality Models.* Electric Power Research Institute. Palo Alto, CA.

EPA 450/4-77-001, *Guidelines for Air Quality Maintenance Planning and Analysis, Volume 10 (Revised): Procedures for Evaluating Air Quality Impact of New Stationary Sources.*

Lesson Goal and Objectives

Goal

To familiarize you with the process called modeling—from determining the need to model to obtaining results—using air quality models.

Objectives

Upon completing this lesson, you should be able to:

1. recognize whether a factory should model under New Source Review procedures, given stack emissions data.
2. name the two kinds of data required for air quality modeling.

3. name the three ways that estimates from an air quality model may be used.
4. name and describe the two types of air quality model analyses.
5. identify one screening model and one refined model.
6. define background concentration.

Supplementary Reading Information

The publications given in the supplementary reading section are generally beyond the scope of this course. However, it is appropriate to summarize the information contained in the readings.

A Review of Methods for Predicting Air Pollution Dispersion gives some reasons for developing air quality models. It puts subjects such as classification of models, source inventory difficulties, meteorological data, and plume rise and dispersion techniques into proper perspective for the student. *A Review* also points out the reason for using the Gaussian plume model instead of more refined approaches such as the Navier-Stokes formulation for atmospheric diffusion.

Appendix D: Available Air Quality Models aids the air quality modeler by placing the models into categories that fit into the specific needs of industry. A specific model can then be selected to fit a specific modeling situation. *Appendix D* also discusses the underlying theory and techniques of the currently available models. The section on local plume and puff models explains why the Gaussian plume technique is so popular in air quality modeling.

The *Guideline, Volume 10 Revised, Procedures for Evaluating Air Quality Impact of New Stationary Sources* was designed to be used for screening a new source when refined air quality modeling may not be necessary. Volume 10 takes the user through plume rise, mixing height, and ground-level concentrations; in effect, all factors necessary to estimate pollution concentrations, for comparison to the National Ambient Air Quality Standards, are calculated.

Introduction to Air Quality Modeling

Slide no. | **Script** | **Selected visuals***

1. Title slide—no narrative

Introduction to Air Quality Modeling

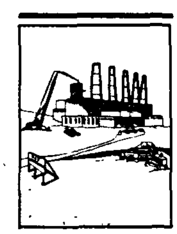
2. In the previous lesson, we introduced the 1977 Clean Air Act Amendments. The Amendments led to the issuance of Federal regulations that require air quality modeling. Because of these regulations, three air quality programs evolved. The three programs we discussed were Prevention of Significant Deterioration, New Source Review, and Control Strategy Evaluation.

- **Prevention of Significant Deterioration**
- **New Source Review**
- **Control Strategy Evaluations**

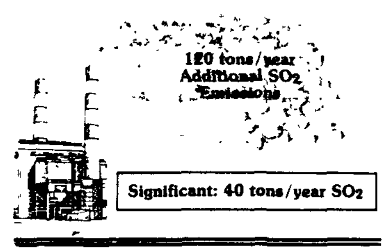
3. To introduce air quality modeling, let's look at the process called modeling. This process involves taking source and meteorological data and analyzing it.

Air Quality Modeling

4. Consider this example. An existing power plant, that is a major source, is to be modified with the addition of a new coal-fired unit and a new smoke stack. Under New Source Review, this power plant must analyze source and meteorological data if its potential emissions will increase by a significant amount.

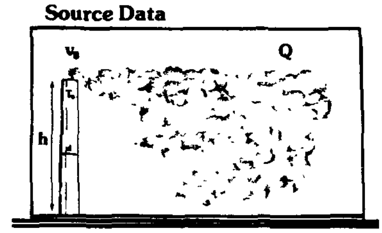


5. The modification to the power plant will result in an additional release of 120 tons per year of sulfur dioxide. This amount exceeds the significance threshold value of 40 tons per year for sulfur dioxide, so modeling and a PSD analysis will be required. There are different significance threshold values for each criteria pollutant. For particulate matter, an increase of only 25 tons per year is defined as significant.



6. In the first step in the modeling process, source data are collected. These data would include the plant's geographic location, stack data such as height (noted by h) and diameter (noted by d), the effluent's temperature (T_s) and velocity (v_s), and the pollutant emission rate (Q).

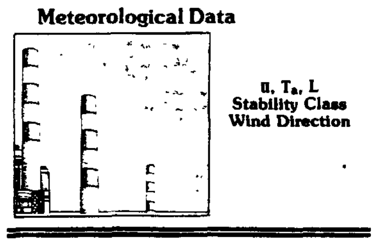
Source Data



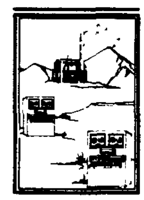
*Illustrations included here, no live shots included.

Slide no.	Script	Selected visuals

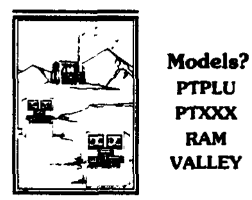
7. Meteorological data from the surrounding area are also collected. These data would include wind speed ($\bar{u}$) and direction, air temperature (T_a), atmospheric stability class, mixing height (L), and the height and location of any obstacles around the plant site. The meteorological data that are gathered must be measured at a representative location of the plant's surroundings.



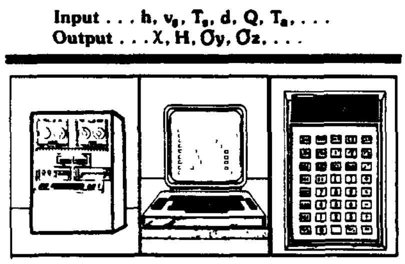
8. A representative location chosen for sampling of meteorological or other data is called a monitoring site. A location where model predictions of pollutant concentrations are made is called a receptor site.



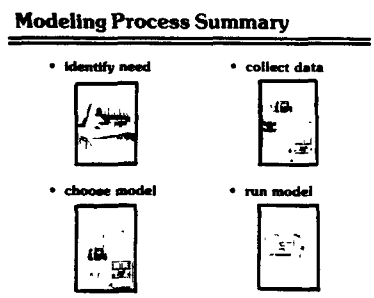
9. After the data have been collected, the second step is to choose a model for the specific situation at the plant. A model is simply a set of mathematical equations. It relates the source emissions to pollutant concentrations in the ambient air.



10. The parameters that make up individual models can be programmed into large computers, minicomputers, and pocket calculators. The source data are entered into the computer or calculator, and the model is run. The run produces output that gives a picture of what happens to pollution as it leaves the stack and is transported and dispersed by the atmosphere.



11. Now that you know what's involved in the modeling process—that is, identifying the need for modeling, collecting the data, choosing the model, and running the model—let's look at air quality models in greater detail.



12. As we said earlier, an air quality model is simply a set of mathematical equations. The equations try to explain the atmospheric interactions taking place as the pollution is released and as it travels to a receptor. The equation shown on this slide is for a Gaussian plume model.

$$\chi = \frac{Q}{\pi \sigma_y \sigma_z \bar{u}} e^{-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2}$$

Slide no.	Script	Selected visuals

13. The model then provides a way of predicting how the pollution from new or existing sources will affect the areas downwind.

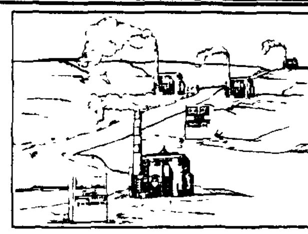
14. These predictions may be used three ways: in developing air pollution control plans, in assessing environmental impact, and in projecting future air quality trends.

Air Quality Model Predictions

1. developing air pollution control plans
2. assessing environmental impact
3. projecting future air quality trends

15. Let's look at these in greater detail. The first use is in developing air pollution control plans. For example, high pollution concentrations are measured in an area downwind from a source. Air quality modeling may be used to identify the specific source that contributed to the excessive concentrations. Once identified, air quality engineers can take action to solve the problem.

Developing Air Pollution Control Plans

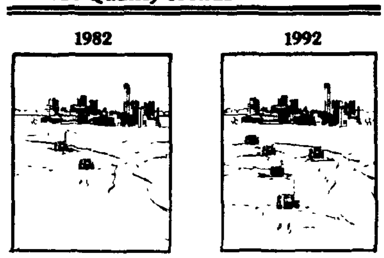


16. Second, air quality models can be used to assess environmental impacts. For example, a new factory will be constructed near an urban area. Modeling must be used by industry consultants to predict how emissions from the factory will affect ambient air quality. Permission to build will be given only if air quality will be maintained after the factory is in operation.

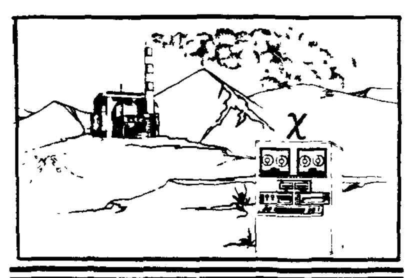
Assessing Environmental Impact

17. Third and last, air quality models can be used to project future air quality trends. For example, a regional planning agency has several options for industrial expansion in a rural county. The impact of each option can be assessed with an air quality model. The model results can be used with other information to rank each option. In this way, environmental factors, like a new industry's effect on air quality, can be weighed and considered in the planning process.

Projecting Future Air Quality Trends



18. As we have seen, modeling lets us logically connect air pollution sources to ambient air quality concentrations, noted by the Greek letter "chi."



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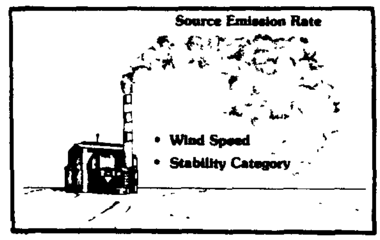
19. Applying a model to a source should be based on two factors: specific use and data requirements. Ask, "How will the specific model be used?" and, "What data are necessary to run this model?"

Model Application

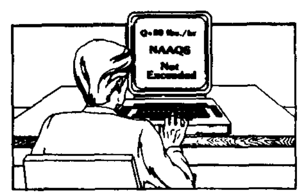
- **Specific Use**
- **Data Requirements**

20. First, a specific model may be used to *screen* the pollution source. That is, a model may be run with limited meteorological data and receptor sites. For example, meteorological data may consist of a small number of possible wind speed and atmospheric stability class combinations.

Screening

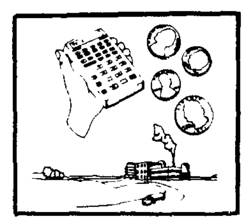


21. The screening method allows a fast estimate of whether the source may cause the National Ambient Air Quality Standards or PSD increments to be exceeded.

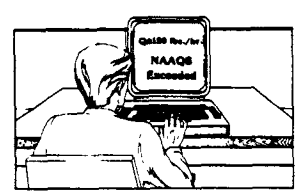


22. The models used for the estimate are not expensive to run, and the mathematical equations are simple to solve. The PTXXX models we'll see later are considered screening models.

Screening

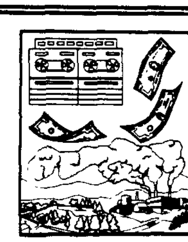


23. The United States Environmental Protection Agency recommends using a screening model first in the modeling process. If the screening model indicates that the source may cause the National Ambient Air Quality Standards or the PSD increments to be exceeded, then a refined analysis must be made.



24. The models used in making a refined analysis are more expensive to run than are screening models. This is because they process large volumes of meteorological data, can consider hundreds of receptor sites, and can simulate complex situations such as downwash or particulate matter deposition. The EPA single source, or CRSTER, model that we will see later is considered a refined model.

Refined Analysis



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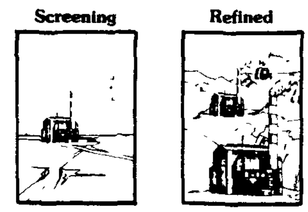
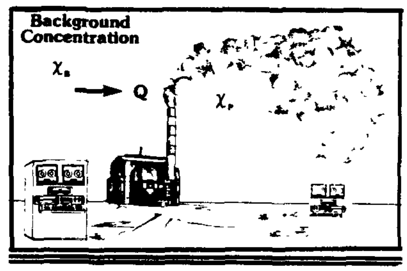
25. Both the screening and refined model analyses will predict air quality based on source emissions and the meteorological conditions.

Air Quality Predictions



26. However, air quality at a specific location also depends on how much pollution is in the air **before** the source adds its own pollution. This quantity is called ***background*** and is represented by "χ_B". The model will predict a concentration, noted as "χ_P".



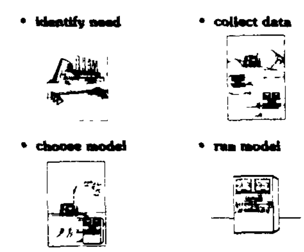
27. To get the total expected concentration, the background concentration is added to the model's predicted concentration. The total concentration is then compared to the National Ambient Air Quality Standards to see if violations will occur. The new source impact, without background, is compared to the PSD increment

Total Concentration = Background Concentration + Predicted Concentration

$$\chi_T = \chi_B + \chi_P$$

28. In this lesson, we have looked briefly at the process of modeling. We have seen that a need must be identified, data collected, a model chosen, and the results obtained.

Modeling Process Summary

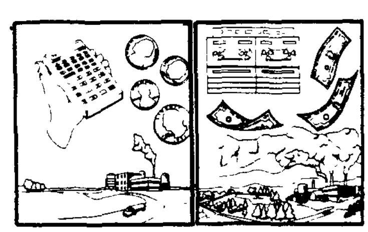


29. We also discovered that air quality model predictions can be used to develop air pollution control plans, to assess environmental impacts, and to project future air quality trends.

Air Quality Model Predictions

1. developing air pollution control plans
2. assessing environmental impact
3. projecting future air quality trends

30. We saw that air quality models can be used to quickly screen air pollution sources. We also saw that air quality models can be used to make a more detailed analysis of sources and their surroundings, if required.



Slide no.	Script	Selected visuals
31.	In the next lesson, we will introduce two case studies that illustrate practical uses of air quality modeling.	**Coming up : Two Case Studies** 
32.	Credit: Crew	**Introduction to Air Quality Modeling** Technical Content: Peter Guldberg Donald Bullard Design: Marilyn Peterson Graphics: Kathy Ward Photography/Audio. David Churchill Narration: Rick Palmer
33.	Credit: NET/EPA Contract	Lecture development and production by: Northrop Services Inc. under EPA Contract No. 68-02-3573
34.	Credit: NET	Northrop Environmental Training

Review Exercise

1. True or False? An expansion of a major source must be modeled if the expansion will increase potential emissions of particulate matter by 25 tons per year or more.	
2. The two kinds of data that must be collected for inclusion in a model are ________ data and ________ data.	1. True
3. A location where model predictions are made is called a ________ site.	2. source, meteorological
4. Ways that a prediction from an air quality model may be used are a. in developing air pollution control plans. b. in assessing impacts. c. in projecting air quality trends. d. all of the above	3. receptor
5. True or False? Screening an industrial site with an air quality model allows a quick look at whether the site is violating NAAQS or PSD increments.	4. d. all of the above
6. True or False? The PTXXX models are considered refined models.	5. True
7. True or False? The EPA single source (CRSTER) model is considered a refined model.	6. False
8. Existing air quality in a specific area before a new factory is built is called the ________ concentration.	7. True
	8. background

Lesson 3
Introduction to Case Studies

Lesson Goal and Objectives

Goal

To introduce two practical cases of modeling.

Objectives

At the end of this lesson, you should be able to:

1. recognize one reason why case studies can be useful.
2. recognize the reason that air quality modeling was necessary in each of the two cases.
3. recognize differences in terrain features and meteorology of the two areas.

Introduction

In Lessons 1 and 2 of this unit, you learned the reasons that air quality modeling is required for Prevention of Significant Deterioration (PSD), New Source Review, and Control Strategy Evaluation. You were also introduced to air quality models—what the process is and what air quality models, in a general sense, are. The reading assignments have also pointed out a painful truth: models come in all sizes and approaches. Consequently, the available models that can be discussed must necessarily be narrowed, since there are so many. The models become very complex as they attempt to fully explain all of the physical processes that influence pollution as it is transported and dispersed in the atmosphere. In this course, you will read about one type of air quality model, the simple Gaussian point source model. This model has been in use for two decades and continues to be useful. It was among the first models to be developed. You will read about eight Gaussian point source models. A course about modeling would not be complete, however, without introducing and examining at least one case study in some detail.

Case Studies

Two case studies will be considered in Unit 6 of this course. They serve as examples of the practical way air quality models have been used by industry. Not all of the point source models that will be discussed were considered for use in the two cases. The case histories concern an oil refinery and an iron-casting plant. Since the two industrial processes are different, the model approaches will be different. The locations are also different: one is in the Southwest, the other in the Great Lakes area. By studying these cases of modeling, you will gain some insight into models and their use.

Oil Refinery

The first case to consider is an oil refinery located in northeastern Oklahoma (Figure 2-1). The oil company that operates the refinery wants to expand the present facility, which will expand the processing capabilities. The plans require building a new stack that will be 35 meters high and 1.56 meters in diameter. The new stack will be located in the vicinity of the older stack, which is 35 meters high and 1.56 meters in diameter. Like the existing stack, the effluent will be SO_2, so there is concern that the new addition will cause the facility to exceed the Class II PSD increments for SO_2. The existing rate is 3.28 grams per second (114 tons per year), and since the emissions exceed 100 tons per year of SO_2, this is already a major source. The new stack will have an effluent rate of 1.5 grams per second (52 tons per year), which is a significant increase in emissions, and, therefore, requires that this source be modeled for PSD. (The

Case study—oil refinery.

Location	NE Oklahoma
Stack proposed	35 m high 1.56 m diam.
Existing stack	35 m high 1.56 m diam.
Effluent	SO_2
Existing rate	3.28 g/s
New stack rate	1.5 g/s
Terrain	Uneven
High point	10 m above stack base
River	West
City	1.61 km east of refinery
Class I PSD areas	None within 50 km

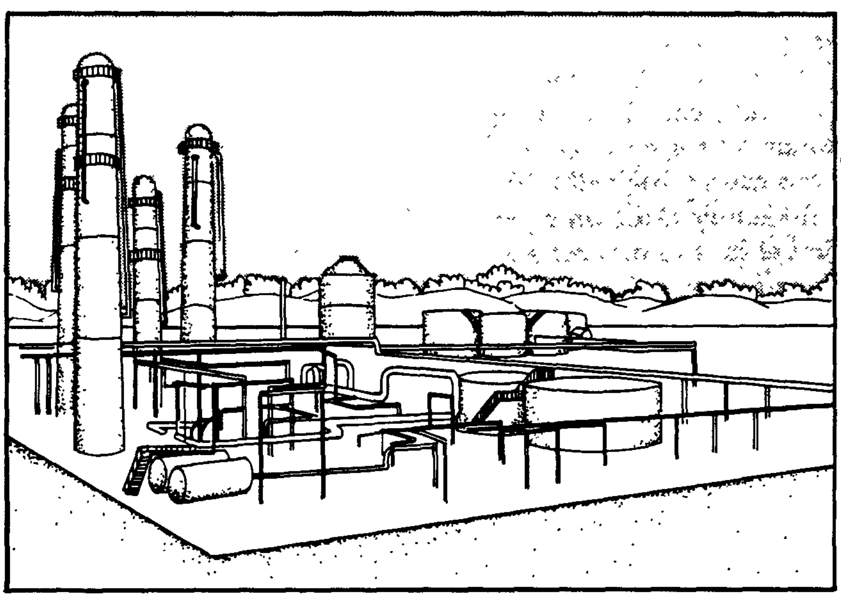


Figure 2-1. Oil refinery.

significance threshold for SO_2 is 40 tons per year or more.) The terrain around the area is uneven with the highest point of land rising 30.8 meters above the base of the stacks. A river runs just west of the refinery. An urban area is located 1.61 kilometers east of the refinery. There are no Federal Class I areas within 50 kilometers.

Iron-casting Plant

The second case to consider is an iron-casting plant (melting furnace) located in northeastern Michigan (Figure 2-2). The company that owns it, a large automobile manufacturer, melts iron ingots in large furnaces before casting automobile engine blocks. No new construction is planned. The company must demonstrate that its effluent does not significantly contribute to the high concentrations of total suspended particulate matter (TSP) observed within the urban area that surrounds it. The area presently exceeds the NAAQS for TSP. The 14 stacks at the iron-casting plant that emit particulate matter average 50 meters in height, but range from 24 to 70 meters. The diameters range from 1.3 to 1.53 meters. The effluent rates of the stacks range from 100 grams per second to 3966 grams per second. The terrain around the area is essentially flat. A very large river runs just northwest. There are no Federal Class I areas within 50 kilometers.

Case study—iron-casting plant.

Location	Northeastern Michigan
Proposed construction	None
Demonstration	Effluent not significant contributor to measured high TSP concentrations
Stacks	14
Height range	24 to 70 m
Average height	50 m
Average diameter	1.3 to 1.53 m
Effluent rate	
1 stack	3966 g/s
2 stacks	3246 g/s
4 stacks	2419 g/s
1 stack	394 g/s
4 stacks	158 g/s
1 stack	100 g/s
Terrain	Flat
River	NW
Class I PSD areas	None within 50 km

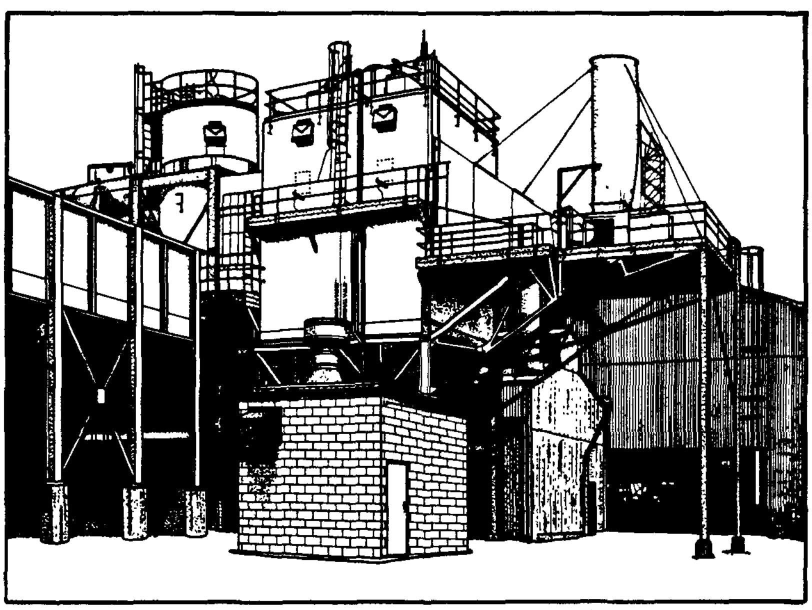


Figure 2-2. Iron-casting plant.

Summary

We introduce the two case studies at this point in the course to encourage you to think about them as you learn about each of the models. As each model is described, think about whether it would be useful in either of the two situations just described. In Unit 6, these two case studies will be considered in more detail. They will be analyzed to illustrate each physical situation and the application of every phase of the modeling process. The models, and why they were chosen, will also be discussed, and, finally, an interpretation of model results (output) will be given. You should compare your choices of models with the model used in each case.

Review Exercise

1. True or False? In the first case study—the oil refinery—the air quality impact of the new stack must be modeled because the proposed expansion will increase SO_2 emissions by a significant amount from a major stationary source.	
2. True or False? One reason case studies of modeling are included in this course is because they help you gain insight into models and their practical use.	1. True
3. True or False? In the second case study—the iron-casting plant—the facility must be modeled for New Source Review.	2. True
4. The two case studies were located in the a. Northwest, Great Salt Lake area. b. Southeast, Great Lakes area. c. Southwest, Great Lakes area. d. Northeast, Great Salt Lake area.	3. False
5. True or False? Both areas had to be modeled because of PSD requirements.	4. c. Southwest, Great Lakes area.
	5. False

Unit 3
Operational Point Source Atmospheric Dispersion Models

Lesson 1
User Considerations in Applying Air Quality Models

Lesson Goal and Objectives

Goal

To introduce you to input data, modeling issues, and some current mathematical models available.

Objectives

At the end of this lesson, you should be able to:

1. list six air pollution problem areas that might require air quality modeling.
2. describe the general output of air quality models.
3. define dispersion model.
4. list the three types of input data to air quality models.
5. define empirical model.
6. define numerical model.
7. classify the Gaussian plume model.

Reading Guidance

The reading assignment introduces some types of models, issues to be considered, and the advantages and disadvantages of these models. Certain topical subjects, like numerical models, will not be discussed further in this course.

Introduction

A dispersion model is a mathematical representation of the transport and diffusion processes that occur in the atmosphere. We have an incomplete understanding of the complex physical and chemical processes involved in the transport, dispersion, transformation, and deposition of pollutants. Because of the turbulent nature of the atmosphere, some limitations to the predictive ability of even the best model will always remain. Uncertainties in emissions and meteorological data also add to model error. Nevertheless, to the extent that models reflect our best understanding of the relevant physical processes, they represent a logical and environmentally equitable basis for decision-making.

Models are used in a variety of environmental planning activities. Some examples include:

- new source review,
- control strategy evaluation for SIPs,
- stack design studies,
- control technology evaluation,
- regulatory variances, and
- fuel conversion studies.

The models that are capable of addressing these issues vary in complexity, required input data, and form of output data.

Input Data

The input data required by an air quality model can be broadly classified as:

- source factors,
- site factors, and
- meteorological factors.

Model input
• Source factors • Site factors • Meteorological factors

Source factors are related to the location and operating characteristics of pollutant emission sources. They include the time variability of emissions and their potential for chemical reaction, deposition, and removal from the atmosphere. Site factors represent the effects of terrain on dispersion and the location of sensitive receptors relative to emission sources. Meteorological factors include all of the parameters that define transport and dispersion of pollutant mass, such as wind and temperature fields, turbulence, and surface roughness.

The actual model used may consider all of these issues, although for certain applications, the model or modeler may only implicitly consider some of them. Complex models require entries for all of these issues; the simpler models do not.

Output Data

The output of air quality models consists of air pollutant concentrations for certain averaging times at specific spatial locations. The time and space detail of the output depends on the characteristics of the chosen model and the model's application. For example, the sequence of annual average concentrations of SO_2 over an urban area is sufficient for determining long-term trends in air quality, but a detailed time and space distribution of SO_2 is required for assessment of short-term extremes in siting new coal-fired power plants in complex terrain.

Model output
• Pollutant concentrations in time and space

Mathematical Models

Mathematical models currently used in the air pollution field range from simple empirical models to very complex numerical models. The empirical models are based on the analysis of air quality data, source emission data, and meteorological data. The numerical models are derived from the basic physical and chemical principles relating to the processes of transport, diffusion, transformation, and removal. Empirical and numerical models are usually partitioned according to the model's tendency to emphasize data or physiochemical principles. However, the differences are not always distinct. For example, empirical models incorporate varying degrees of physical insight, such as accounting for the transport and the spatial distribution of emissions in the source-receptor relationships. Conversely, numerical models rely on empirically determined parameters, such as transformation rates, removal rate constants, and coagulation coefficients. Thus, a family of models, or model hierarchy, exists, ranging from simple rollback models to highly complex photochemical models.

Model hierarchy
• Simple rollback • Screening • Refined • Complex photochemical

Semi-empirical Models

Semi-empirical is often used as an intermediate category of air quality models. The Gaussian models, most widely used at the present time, are semi-empirical. These models are derived from scientific principles (e.g., conservation of mass), but rely on empirically defined parameters (e.g., dispersion rates).

Empirical Models

Empirical models, which are closely tied to meteorological and emission data bases, allow a full exploration of available information in these bases. Relying on meteorological observations allows the complexities of the atmospheric system to be represented, even though some complexities are not fully understood. Also, empirical approaches allow a simultaneous check on data quality through standard statistical tests. Finally, empirical models can usually be formulated and operated at low cost.

However, depending on meteorological and emission data bases, disadvantages may occur for empirical modeling. Some empirical models require high quality data, which often do not exist. Additionally, empirical models and their parameters are very closely tied to the specific conditions under which they were created. As a result, when they are applied to other meteorological situations in the same locale, the models may lead to incorrect conclusions. Careful selection of variables and thoughtful interpretations of observed relationships can counteract some of the disadvantages.

Numerical Models

Numerical models are formulated from basic scientific concepts associated with physical and chemical processes occurring in the atmosphere. This formulation affords confidence in their application over various ranges of conditions and areas, as well as in their predictive ability. However, these models possess computational complexities, and require extensive data input and specifications of numerous model parameters. The semi-empirical models share advantages and disadvantages of both the empirical and numerical models.

Review Exercise

1. List six air pollution problem areas that might require air quality modeling.	
2. The output of air quality models consists of ________.	1. • new source review • control strategy evaluation for SIPs • stack design studies • control technology evaluation • regulatory variances • fuel conversion studies
3. Define a dispersion model.	2. air pollutant concentrations in time and space
4. List the three types of input data to air quality models.	3. A dispersion model is a mathematical representation of the transport and diffusion processes that occur in the atmosphere.
5. Define empirical model.	4. • source factors • site factors • meteorological factors
	5. Empirical models are models based on analyzing three kinds of data: air quality, emission, and meteorological.

6. Define numerical model.	
7. True or False? The Gaussian plume model is a semi-empirical formulation.	6. Numerical models are derived from basic physical and chemical principles that relate to the processes of transport, diffusion, transformation, and removal.
	7. True

Lesson 2
Characteristics of Model Classes

Supplementary Reading

DOE/TIC-11223, *Handbook on Atmospheric Diffusion,* U.S. Department of Energy, 1982, chapters 1, 2, and 10.

Lesson Goal and Objectives

Goal

To familiarize you with the characteristics that are used to refine air quality model classes.

Objectives

At the end of this lesson, you should be able to:

1. list eight model characteristics.
2. describe the reason that the distances between grid points in air quality models are limited by the meteorological scales of motion.
3. state the reason air quality models may be called time-varying models.
4. list two reasons that Lagrangian air quality models are more capable of describing atmospheric processes than Eulerian air quality models.
5. list two reasons that emission data inputs to air quality models may be incorrect in estimating pollution concentrations.
6. list two reasons that meteorological data inputs to air quality models may be incorrect in estimating pollution concentrations.
7. list two reasons that an air quality model may not be representative of the problems in estimating pollution concentrations.

Model Characteristics*

Model characteristics
Time and space scales
Steady state or time dependent
Frame of reference
Pollutants and reaction mechanisms
Treatment of turbulence
Multiple plumes
Treatment of topography
Treatment of uncertainty

The air pathway processes that control the fate of pollutants from source to receptor are transport, diffusion, transformation, and removal. Because of the complexity of these processes, as well as the complications introduced by terrain and the pollutants themselves, there exists a large and diverse family of air quality models.

The members of the family of air quality models, in the empirical, semi-empirical and numerical categories, possess a variety of characteristics that can be used to further refine model classification. These characteristics are a result of the ambient meteorological and topographical conditions, the time and space scales inherent in the model application, the mathematical procedures used to solve the system of equations, and the pollutants and reaction mechanisms required to answer the particular air quality question.

Time and Space Scales

Air pollution decisions can be described in terms of four geographical subdivisions: site specific (local), regional, national, and global (Figure 3-1). These form a reasonable classification scheme for horizontal spatial and time scales of air quality models. At the lower end of the scale, site-specific, or local, situations include considerations such as emissions, source characteristics, initial plume rise, initial phase of mixing, local terrain, and initial transport. At the higher end, the site-specific category is concerned with interacting plumes from sources separated by 10 to 20 km.

Regional-scale problems range from an urban area or large industrial complex to a region where urban areas are point sources in the air quality models. For example, the lower limit of the scale may be represented by a nocturnal urban plume, while the northeast quarter of the continental U.S. represents the upper limit of the regional scales.

National scales vary from half of the continental U.S. to the entire continental U.S. For example, models have been used to estimate the SO_2 concentrations from existing sources west of 100°W longitude for a high-coal-use electric scenario projected to the year 2000. Currently, the Department of Energy is conducting a national coal assessment that will estimate SO_2 concentrations over the entire continental U.S.

Although global decisions may be concerned with global problems and models, once a pollutant crosses international boundaries, international decisions may be required. The

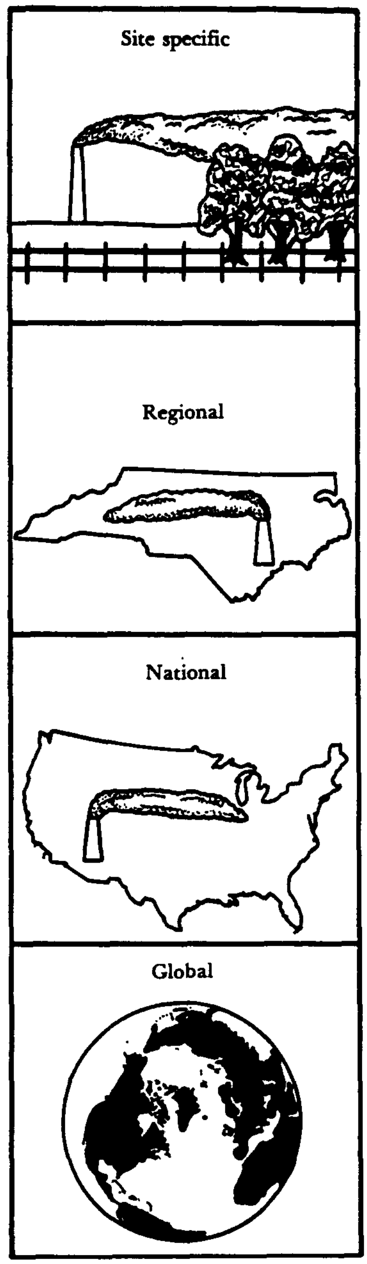


Figure 3-1. Time and space scales.

*Source: EPRI EA-1311, Section 2, pages 2-1 through 2-13.

models used to help resolve these problems will be of a scale geometrically smaller than global. However, two important global problems whose impacts are independent of national boundaries are the effects on weather and climate of substantial increases of CO_2 and fine particles in the atmosphere.

The determination of time scales from the model application point-of-view depends on the effects of the pollutant, the regulatory standards, and the variability of emissions and meteorology. Odor and taste perception is nearly instantaneous; possible acute toxic effects on humans and animals occur over periods of hours; and chronic effects occur over seasons and years (Figure 3-2). Regulatory standards are usually closely related to time scales of expected effects. Emission variability depends on power demand curves and possible accidental releases, while variability in meteorology depends on turbulence, passing thunderstorms and weather fronts, and stationary air masses.

The air quality model (AQM) will calculate pollution concentrations at preselected times and locations called grid points (Figure 3-3). The user determines the times and grid locations desired. The outcome of an AQM is highly dependent on the availability of the meteorological input data. That is the distance between sampling stations and the time period for which the data is averaged. The model's ability to calculate at optimum grid points, using the smallest possible distances at time intervals, is called resolution. Consequently, meteorological observing stations cannot detect weather disturbances that are smaller than one-half the distance from one station to the next. The ability to "see" only certain sizes of phenomena limits the model's forecasting ability.

For example, using Table 3-1, local atmospheric phenomena, such as sea breezes, are approximately 2 kilometers at the smallest, or L_{min} (Figure 3-4). This means the smallest grid size distance that can be used for calculations in a local model is one-half of L_{min}. Local grid sizes are not closer than 1 kilometer apart. The time average of the calculations is on the order of an hour. A large number of calculations are needed to estimate concentrations across atmospheric scales. There is a limit on the number of grid points that can be economically used to fit the scales. There are approximately 100 grid points in each horizontal direction.

Models with length scales less than global or hemispheric require time-dependent, lateral boundary conditions so that features with $L_{max}/4$ scales are properly resolved. This limitation on the scales spanned by atmospheric models implies that a user can expect broad coverage or detailed interaction, but not both. Boundary conditions must always be specified, while subgrid scale processes must always be given parameterized values.

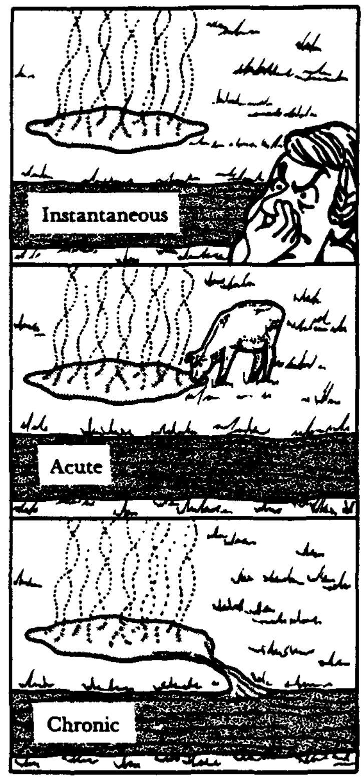


Figure 3-2. Pollution effects.

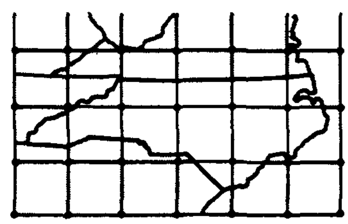


Figure 3-3. Grid points for regional scale.

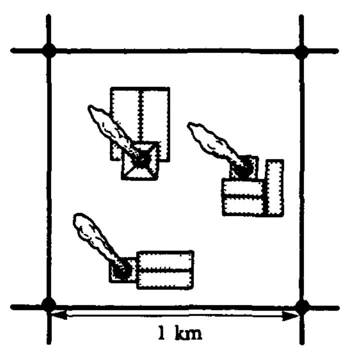


Figure 3-4. Grid points for local scale.

Table 3-1. Atmospheric scales: model scope, characteristic length and time scales of phenomena, and examples.

Atmospheric scales	Model			Length	Time	Phenomena
	Grid (km)	L_{min} (km)	L_{max} (km)	$L \sim \lambda/4$ (km)	$\tau \sim P/4$	
Global	400	800	40,000	10,000	3 m	season climate zone
Hemispheric	200	400	20,000	3,000	10 d	spell storm track
Continental	100	200	10,000	1,000	3 d	air mass anticyclone cyclone
Regional	20	40	2,000	200	3 hr	front squall
Local	1	2	100	10	1 hr	sea-breeze heat island
Convective	0.04	0.08	4.00	1	15 min	shower tornado
Turbulent	0.01	0.02	1.00	0.2	1 min	plume eddy gust

Source: Adapted from *Atmospheric Modeling Relative to Fuel Use Strategy*, presented at BNL Conf. on Energy Related Modeling and Data Base Management, May 12-14, 1975, p. 8.

The current state of affairs in understanding the atmospheric phenomena in Table 3-1 is as follows:

- There is much to learn about climate change due to solar radiation and the distribution of continents and mountains. But the greatest challenge is to understand the causes for very small changes in climate that have major impacts on society in areas with marginal climates. The forcing functions for these small changes are radiation fluxes and turbulent fluxes of heat, moisture and momentum from the surface, along with the radiative influences of clouds. Little is known about the effects of these phenomena on local and regional climate.
- Anticyclones and cyclones, outside of the tropics, are the easiest important phenomena to understand, treat theoretically, and predict (Figure 3-5).
- Regional, local, and convective scales include very complex processes that depend on underlying topography, latent heat releases, and nonlinear interactions and feedback mechanisms between scales that are larger and smaller than the phenomenon in question. These areas suffer from a lack of data from routine measurements, special field projects, and numerical simulation.

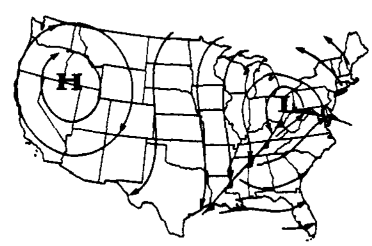


Figure 3-5. Anticyclones and cyclones.

- Considerable advances have occurred in modeling turbulent boundary layer flows over homogeneous terrain and turbulent diffusion over uniform surfaces, for distances out to 10 to 20 km. However, over irregular terrain and urban areas, the prediction of pollutant trajectories is still difficult (Figure 3-6).

This paucity of atmospheric data is reflected in the current status of weather forecasting (Table 3-2). Statistical techniques are used beyond prediction periods of five days; equations of fluid dynamics for periods of 18 hours to several days; simple translation or extrapolation of patterns is used for two to six hours; and persistence of observed conditions is reliable for two hours. In summary, the physical science of atmospheric prediction is relatively advanced for time scales of 18 to 72 hours; beyond this period, statistical science dominates, and for shorter periods, instrumentation and data processing dominate.

Since AQM's cannot be better than their atmospheric elements, the conclusions given above concerning the time and space modeling scales in Table 3-1, the state-of-affairs in atmospheric sciences, and the state-of-forecasting in Table 3-2, are equally valid for AQM's. Additionally, the grid and resolvable scales listed in Table 3-1 can be used for characteristic lengths in the AQM's.

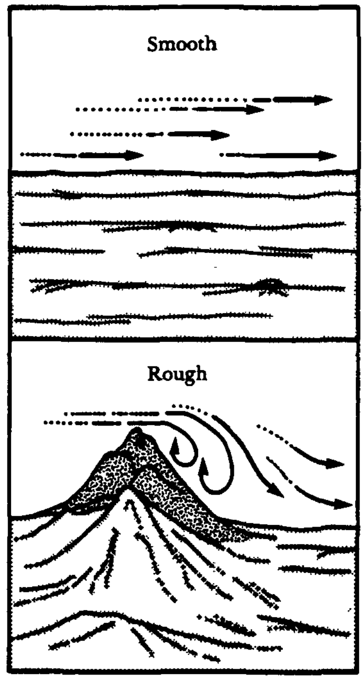


Figure 3-6. Smooth to rough transition.

Table 3-2. Techniques of weather forecasting.

Period	Name	Domain of data	Method	Quality
Beyond 3 months	(experimental)	global	climatological statistics	vague
1 to 3 months	seasonal	global	statistics	unproved
6 to 30 days	outlook	global	statistics	vague and little proved
3 to 5 days	extended	hemisphere	statistics and dynamics	good to poor... erratic
18 to 72 hours	intermediate	hemisphere	dynamics	good except for precipitation
2 to 18 hours	short range	300 to 3000 km	statistics dynamics (6 to 18) translation (2 to 6)	fair
0 to 2 hours	nowcast	0 to 300 km	persistence	as good as data processing, communications, and display

Source: Adapted from *Atmospheric Modeling Relative to Fuel Use Strategy*, presented at BNL Conf. on Energy Related Modeling and Data Base Management, May 12-14, 1975, p. 10.

Steady-state or Time-dependent Models

Models are steady state or time varying, depending on whether or not time is explicit in their formulation. If the system of equations governing the phenomena being studied in the model depends on time, the model is time varying. If the system represents the average state of phenomena over a certain period of time, the model is steady state.

Steady-state models are applicable when the time and space scales are sufficiently small, or when the desired output is sufficiently coarse that variability in the effects of pollutants, emissions, and meteorology can be ignored or averaged out (Figure 3-7). For example, the steady-state Gaussian plume can be used over site-specific scales if the winds and atmospheric thermal structure are nearly uniform over the time period of interest. Steady-state models can be used for certain policy- and standard-setting decisions on the regional and global scales. However, for technological assessments on the regional and global scales, time-varying models must be used to account for the variability in meteorology and emissions. Whenever steady-state models can be used in place of time-varying models, there is a saving in computer time and cost.

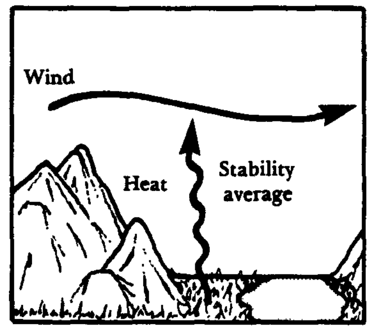


Figure 3-7. Steady-state meteorology conditions.

Frame of Reference

Air quality models, except for some empirical ones, are related to a coordinate system, or reference frame (Figure 3-8). Reference frames may be fixed at the earth's surface, at the source of the pollutant (for either fixed or moving sources), or on a puff of pollutant as it moves downwind from the source. Reference frames fixed at the earth's surface or on the source are called Eulerian (because of their relation to the advecting and diffusing pollutant), while frames fixed on a puff of pollutant are called Lagrangian.

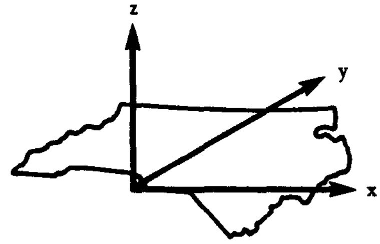


Figure 3-8. Reference frame coordinate system.

The advantage of Lagrangian models over Eulerian models, and vice versa, depends on the class of models and the availability of the proper input data. Turbulent diffusion of pollutants is more easily formulated in the Lagrangian sense, but most of the pollutant concentration data have been obtained in the Eulerian sense. No adequate theoretical basis exists for converting Eulerian diffusion data to Lagrangian data. Hence, some of the advantages of Lagrangian models given below may suffer from this lack of adequate input data.

Lagrangian models are more capable than Eulerian models of accounting for source locations and emission rates and of describing diffusion as the pollutants are carried by the wind. On the other hand, Eulerian models are more capable of accounting for topography, atmospheric thermal structure, and reactive pollutants from many sources. Lagrangian trajectory models are less costly to run than Eulerian models and are adequate for regional long-term assessments, while three-dimensional Eulerian models are best for the analysis of such phenomena as a photochemical smog episode in the Los Angeles basin.

Pollutants and Reaction Mechanisms

Air quality models describe the fate of airborne gases and particles. As these pollutants travel over their pathways, physical and chemical reactions may occur. As shown in Figure 3-9, the categories of mechanisms are nonreactive, reactive (photochemical and nonphotochemical), gas-to-particle conversions, gas/particle processes, and particle/particle processes. In addition, the gases and particles may be radioactive, in which case the models must contain some provisions for accounting for radioactive decay and the production of subsequent radioactive elements.

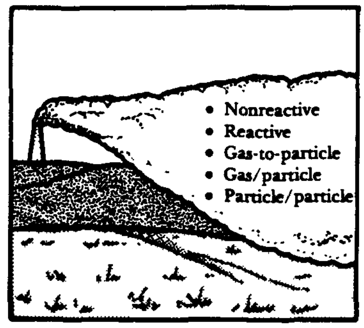


Figure 3-9. Airborne gas and particle conversions.

Nonreactive models have been constructed to determine the fate of automobile emissions of CO and emissions of particulate matter from fossil-fuel power plants (Figure 3-10). Reactive models have been developed to determine the formation of sulfate deposits from SO_2 emissions from coal-fired power plants. On hot, sunny days, in areas like the Los Angeles basin and Houston, complex photochemical models predict the formation and concentration of oxidants from hydrocarbon and NO_x emissions for both moving and stationary sources (Figure 3-11).

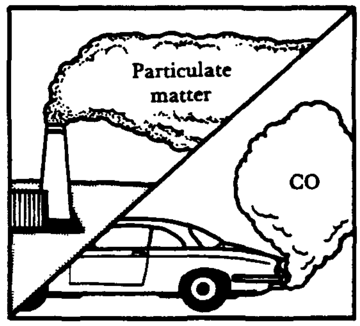


Figure 3-10. Nonreactive emissions.

Both the SO_2/sulfate and photochemical models have gas-to-particle and gas/particle components. The gas-to-particle components account for the production of particles directly from gases via gaseous reactions or via condensation. The gas/particle components in the models account for particle growth by condensation or by absorption of gases. Particle/particle processes are accounted for in aerosol models. These are similar to nonreactive gas models, except that particle components are added to the equations. These components include coagulation (collision followed by sticking together), breakup, condensational growth, and diffusion.

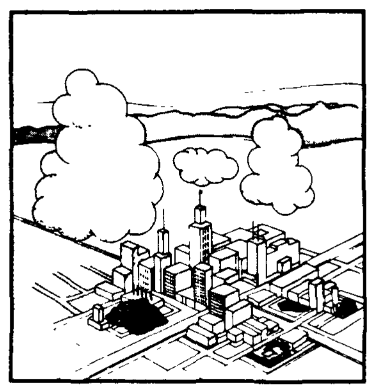


Figure 3-11. Reactive emissions.

Treatment of Turbulence

Atmospheric turbulence, shown in Figure 3-12, is the mechanism that dilutes and mixes the gaseous and particulate pollutants as they are transported by the mean wind. Turbulence is one of the least known, but one of the most important, phenomena in the atmosphere, and it is produced when certain gradients in the wind, temperature and humidity fields occur in the atmosphere. For these reasons the formulation of turbulence in air quality models ranges from the simple (a well-mixed or stirred volume) to the complex (accounting for both local and historical influences of turbulence on velocity fields).

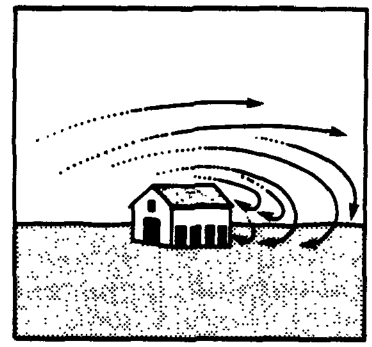


Figure 3-12. Atmospheric turbulence.

Atmospheric turbulence in a model may be provided for by a well-mixed volume, semi-empirical diffusion coefficients, eddy diffusivity, Lagrangian statistics, or more complex turbulence models. The well-mixed volume approach, as in rollback and simple box models, basically ignores turbulence except in a loosely implicit manner. Semi-empirical diffusion coefficients are the main parameters in the current air quality models: Gaussian plume and puff (Figure 3-13). These coefficients have been determined from field diffusion studies over flat terrain and usually under neutral stability conditions. Most working grid and multibox models use the eddy diffusivity formulation, which is based on theoretical, physical, and numerical studies of the planetary boundary layer.

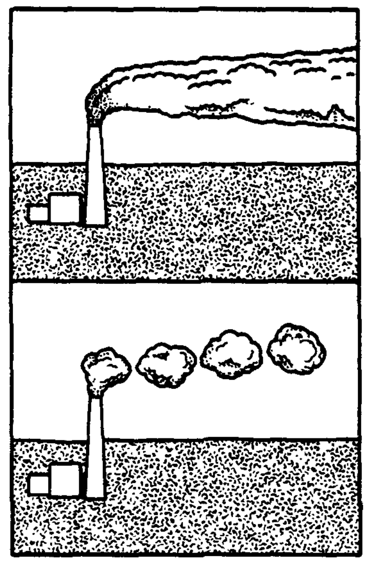


Figure 3-13. Gaussian plume and puff.

To account for some of the physical inconsistencies in the eddy diffusivity formulation, more complex formulations have been developed. These turbulence models, which contain many parameters and new dependent variables, increase the number of equations in air quality models. The models also increase the number of parameters that need to be specified, introduce new uncertainties, and increase the computer costs of running air quality models.

In spite of these additional considerations, these complex turbulence formulations are seen as necessary for numerical stability and accuracy in grid models, as well as for analysis and prediction of complex reaction mechanisms in power plant plumes.

Another approach for introducing more realistic turbulence into a diffusing system is to apply Lagrangian statistics. The statistics of turbulent diffusion following puffs of pollutants are mathematically more simple than those of the Eulerian approach. Most field data, however, are obtained in the Eulerian sense, and the relationship between Eulerian and Lagrangian statistics is unknown for atmospheric turbulence in the planetary boundary layer. Therefore, the only real advance in this area has been for numerically simulated turbulent fields, not for diffusion fields in the real atmosphere.

Multiple Plumes

The assumption that nonreactive pollutant plumes can be added together is illustrated in Figure 3-14. Suppose an air quality model is used to calculate concentrations of an i-th pollutant (c_i) in the plumes from Plant A and Plant B. Concentrations of the i-th pollutant from the combined plants are calculated by simply adding the contributions from Plant A, c_i (x,t;A), and Plant B, c_i (x,t;B), together for common spatial (x) and time (t) positions. The validity of this assumption depends on physical and chemical noninteraction between the i-th pollutant in the two plumes. The principal advantage of the property is the saving in computer time and storage for regional and national assessments where tens to hundreds of sources must be considered.

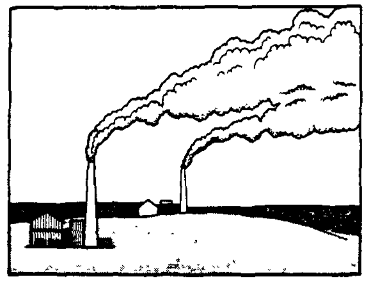


Figure 3-14. Plume additivity.

Treatment of Topography

Surface conditions and topographic features generate fields of turbulence, modify vertical and horizontal winds, and change the temperature and humidity distributions in the boundary layer. All of these changes modify the transport and diffusion of pollutants. An important characteristic of air quality models is the manner in which surface conditions and topography are treated.

Topography is characterized in air quality models as homogeneous flat terrain, nonhomogeneous flat terrain, simple terrain, and complex terrain. Examples of homogeneous flat terrain are shown in Figure 3-15; the grasslands of western Kansas, the corn fields of Ohio and Iowa, and the pine forests of the Southeast. The greatest number of experimental diffusion studies have taken place over homogeneous terrain; therefore, air quality models based on diffusion coefficients and eddy diffusivities are most applicable for this topographic category.

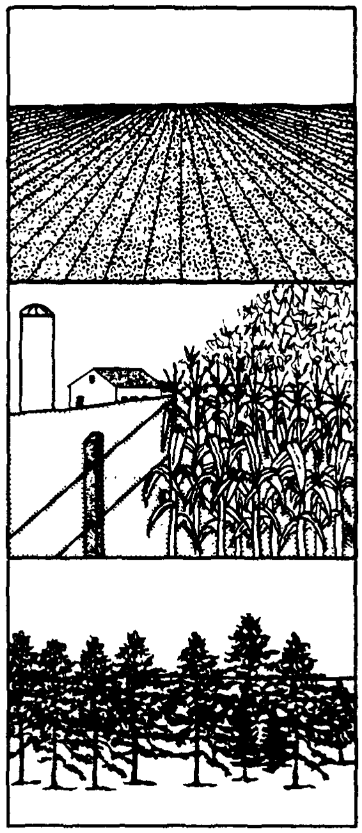


Figure 3-15. Terrain features.

Nonhomogeneous flat terrain includes water-land transitions, transitions from grasslands to forests, and transitions from irrigated farmland to desert areas.

Simple terrain includes street canyons in urban areas, simple deep valleys, sharp-edged cliffs, and simple hills. Figure 3-16 depicts two views of the flow of pollutants around a simple hill under stable atmospheric conditions.

Figure 3-17 indicates the effects of lateral drainage winds, known as katabatic winds, on pollutants. Even though the pollutants may initially escape from the valley, the nighttime drainage situation has a tendency to recirculate the pollutants so that they finally accumulate in the valley.

Figure 3-18 illustrates the terrain downwash effect of siting a power plant in the lee of a sharp-edged cliff. Terrain downwash may produce high concentrations of pollutants near the source. S and S[1] represent stagnation points in the flow field, while the dashed line represents the surface of separation between streamline flow and the revolving rotor.

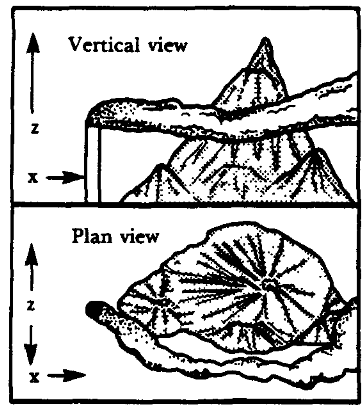


Figure 3-16. Transport of a plume around the side of a hill under stable atmospheric conditions.

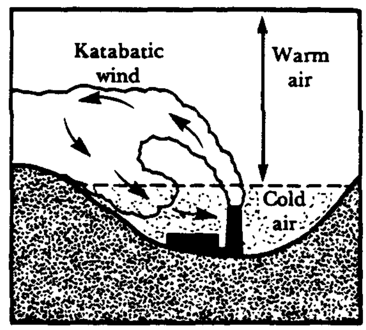


Figure 3-17. Pollutant accumulation in valley.

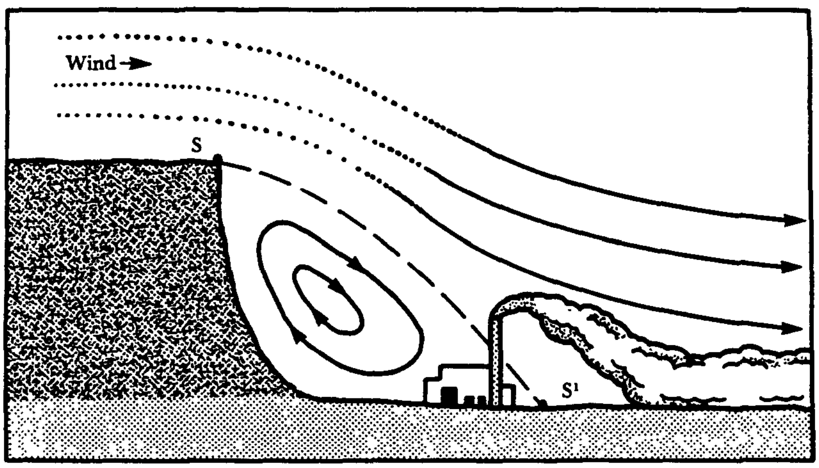


Figure 3-18. Terrain downwash.

Complex terrain consists of mountain ranges and deep valleys such as those found in the Rocky Mountains and the Northern Appalachians. In these areas the wind and temperature fields are very complex, as are the distribution and intensity of atmospheric turbulence. At latitudes closer to the equator, photochemical reactions should be more pronounced than at latitudes toward the poles because the intensity of sunlight is greater. Because of these complexities and the sparseness of monitoring stations, experimental data on flow, diffusion, and photochemical reactions in complex terrain is fragmentary and incomplete. Better data and models in complex terrain are needed because of the availability of energy in the mountainous West, which increases the sitings of power plants, and the requirement for preventing significant deterioration of pristine areas.

Treatment of Uncertainty

Many sources of errors and/or uncertainties occur in pollutant concentrations obtained from air quality models. The emissions data that are inputs to these models may be in error because of incorrect source strengths and locations, unaccounted for time variability in emission rates, uncertainties in stack parameters, and incorrect calculations of plume rise after emissions. Meteorological data that are used for model inputs and for evaluating model parameters may be in error because of incorrect calculations of plume rise after emissions. Meteorological data that are used for model inputs and for evaluating model parameters may be in error because of incorrect wind speed and direction, poorly specified dispersion parameters, and incorrect determination of the atmospheric thermal structure. The air quality model itself may not be representative of the problems in question because of incomplete knowledge of chemical and physical interactions of gases and particles, incorrect formulations of removal processes, and poorly specified boundary conditions.

The treatment of physical and chemical uncertainties has resulted in the following classification scheme for models:

Model classifications for uncertainty
Deterministic Stochastic Adaptive

- Deterministic, if the formulation of the model is in terms of specific constants, functions, and parameters.
- Stochastic, if the information concerning the physical process is not entirely known but the underlying structure is. That is, the detailed information is random, but specific tools exist to solve the system.
- Adaptive, if the basic structure of the process is unknown. However, in this system more is learned as one sets about determining the solution and the basic structure begins to evolve. Examples of this type of system in air quality modeling are complex photochemical reaction schemes, gas/particle and particle/particle systems.

Although most current air quality models are deterministic, some models are truly stochastic and a few are adaptive. In fact, all air quality models representing specific real-world situations have features that are either explicity or implicitly adaptive. The basic reasons for adaptive systems are uncertainty in meteorological data; incomplete knowledge of atmospheric turbulence; ignorance of chemical reactions and reaction rates in the atmosphere; incomplete knowledge of the chemical species from, and the emission characteristics of, natural sources; and lack of data and knowledge of gas-to-particle and particle/particle interactions.

Current investigations are trying to remove, or at least reduce, these areas of uncertainty. For example, there are currently three large field experiments in the northeastern quarter of the United States dealing with the conversion of SO_2 to sulfate: EPA's Sulfate Transport and Transformation in the Environment (STATE), DOE's Multistate Atmospheric Power Production Pollution Study (MAP3S), and EPRI's Sulfate Regional Experiment (SURE).

Field experiments
EPA's STATE DOE's MAP3S EPRI's SURE

Review Exercise

1. List the eight model characteristics discussed in this lesson.	
2. True or False? A limitation on length scales is used in air quality models because the user can either get fine detail or broad coverage of pollution estimates but not both.	1. • time and space scales • steady state or time dependent • frame of reference • pollutants and reaction mechanisms • treatment of turbulence • multiple plumes • treatment of topography • treatment of uncertainty
3. True or False? A model is called time varying because its equations depend on time.	2. True
4. The Lagrangian models are more capable of describing reality than the Eulerian models because a. the Lagrangian uses anemometer information from the NWS. b. Lagrangian mathematics are simpler to solve than Eulerian mathematics. c. Lagrangian models can acccount for source location and emission rates. d. Eulerian models require meteorological information from balloons for accuracy.	3. True
5. Emission data may be incorrect because of a. uncertainties in stack parameters. b. incorrect calculations of emission plume rise. c. both a and b	4. c. Lagrangian models can account for source location and emission rates.
	5. c. both a and b

6. Meteorological data can be incorrect because a. windspeed and direction are taken with an anemometer only. b. windspeed and direction are taken with a tethered balloon only. c. dispersion parameters may be poorly specified. d. the stability of the atmosphere is well known and need not be measured.	
7. An air quality model used may **not** be representative of a modeling situation because a. modeling is accurate only in California. b. modeling is not required under any circumstances. c. removal processes are never required in a model. d. boundary conditions are poorly specified.	6. c. dispersion parameters may be poorly specified.
	7. d. boundary conditions are poorly specified.

Lesson 3
Applications of Air Quality Models

Lesson Goal and Objectives

Goal

To familiarize you with the way air quality models are applied in making decisions.

Objectives

At the end of this lesson, you should be able to:

1. name the nine model subdivisions that aid in deciding if professional modeling consultants are required.
2. match air pollution applications and geographical decision scales to their representative sizes.
3. decide from a site-specific fuel choice problem which model subclass to use in determining air quality.

Introduction

Air quality models treat air pollutants as they travel between the source and the receptor. The models accept the emission characterisics of pollutants as input and produce estimates of ambient air concentrations and material deposited on surfaces as output. This output is then used to analyze the impacts and effects of pollutants on receptors, weather, and climate. Model applications may be summarized as follows.

Applications and Decisions

Air pollution applications and decisions can be geographically divided into site-specific areas, with horizontal spatial scales from 1 to 20 km; regional, with scales from 20 to 1000 km; national, with 1000 km to continental United States; and global, with hemispherical to global. Important decisions on the local, or site-specific, scale are concerned with the choice of fuel during air pollution episodes or on a continuing basis, the type of abatement technology that should be employed in a power plant, and the choice of when and where to monitor air

Air pollution applications and decisions.

Area	Horizontal spatial scale
Site specific	1 to 20 km
Regional	20 to 1000 km
National	1000 km to continental U.S.
Global	Hemispherical to global

quality. In addition, new power plants must be analyzed in regard to their production of incremental changes in air quality over pristine areas.

Decisions on the regional scale involve plant siting of large power units, the assessment of the effects on air quality as a result of given or new technologies, when and where to monitor air quality, land use planning, and setting of emission standards to satisfy ambient air quality regulations. National decisions should address technological assessment, choice of research and development programs, and the national energy policy. Finally, global decisions should treat assessment problems, such as the increase of CO_2 and fine particles in the air, or address the international energy policy.

Subclasses

In arriving at these decisions, air quality models are often used. The nine model subclasses are as follows: rollback, statistical, local Gaussian plume and puff, regional trajectory, box and multibox, grid, particle, global, and physical. Table 3-1 summarizes the characteristics of these nine model subclasses. These characteristics help decision makers understand the type and complexity of the model subclass and aid in determining whether the modeling work should be done in-house or by a consulting firm.

Decision Table

Table 3-2 indicates what class of models should be used for a given decision. In addition to the model class, the table indicates the important time scales that should be used, and whether or not the models should contain transport and diffusion, transformation, and removal components. The use of these tables will aid decision makers in realistically treating the air pathway segment of the air pollution decision process.

Table 3-1. Summary of model subclasses.

Model subclass	Model class	Geographical subdivisions	Steady state or time dependent	Frame of reference	Type of pollutants	Reaction mechanisms	Treatment of turbulence	Plume additivity	Treatment of topography	Treatment of model uncertainty
Rollback	Empirical	Local Regional National	Steady state	Eulerian	Gases and particles	Nonreactive	Well-mixed	Not applicable	Homogeneous to simple terrain	Deterministic
Statistical	Empirical	Local Regional	Steady state Time dependent	Eulerian	Gases and particles	Nonreactive Reactive Gas-to-particle	Well-mixed	Not applicable	Homogeneous to simple terrain	Stochastic Adaptive
Gaussian plume and puff	Semi-empirical	Local	Steady state Time dependent	Eulerian Lagrangian	Gases and particles	Nonreactive Reactive	Diffusion Coefficients	Yes and no	Homogeneous to complex terrain	Deterministic
Regional trajectory	Semi-empirical	Regional National	Time dependent	Lagrangian mixed Lagrangian and Eulerian	Gases and particles	Nonreactive Reactive	Diffusion Coefficients Eddy Diffusivities	Yes	Non-homogeneous to complex terrain	Deterministic Stochastic
Box and multibox	Semi-empirical and meteoro-chemical	Local Regional	Steady state Time dependent	Eulerian Lagrangian	Gases and particles	Nonreactive Reactive Gas-to-particle	Well-mixed Eddy Diffusivities	Yes and no	Homogeneous to simple terrain	Deterministic
Grid	Numerical	Local Regional	Steady state Time dependent	Eulerian	Gases and particles	Nonreactive Reactive Gas-to-particle	Eddy Diffusivities Complex Formulation	Yes and no	Homogeneous to complex terrain	Deterministic
Particle	Numerical	Local Regional	Time dependent	Mixed Lagrangian and Eulerian	Gases and particles	Nonreactive Reactive Gas-to-particle	Eddy Diffusivities	Yes and no	Homogeneous to complex terrain	Deterministic Stochastic
Global	Numerical	Global	Time dependent	Eulerian	Gases and particles	Nonreactive Reactive	Eddy Diffusivities	Yes	Non-homogeneous to complex terrain	Deterministic
Physical	Empirical	Local	Time dependent	Mixed Eulerian and Lagrangian	Gases and particles	Nonreactive	Not applicable	Not applicable	Homogeneous to complex terrain	Deterministic

Table 3-2. Decisions and model applications.

Decision	Model subclass	Averaging time or temporal scales	Need for transport and diffusion components	Need for transformation or wet and dry removal components
Site specific (1 to 20 km spatial scale)				
Fuel choice	Rollback	Weekly to annual	No	No
	Statistical	Hourly to daily	No	No
	Gaussian plume and puff	2 min to 2 hr	Yes	Yes and no
Abatement technology	Rollback	Weekly to annual	No	No
	Statistical	Hourly to daily	No	No
	Gaussian plume and puff	2 min to 2 hr	Yes	Yes and no
Incremental changes	Gaussian plume and puff	2 min to 2 hr	Yes	Yes and no
	Grid	2 min to 2 hr	Yes	Yes and no
Monitoring	Gaussian plume and puff	2 min to 2 hr	Yes	Yes and no
Regional (20 to 1000 km spatial scale)				
Plant siting	Regional trajectory	2 hr to 4 d	Yes	Yes
	Grid	2 hr to 4 d	Yes	Yes
	Multibox	2 hr to 4 d	Yes	Yes
Technological assessment	Regional trajectory	Monthly to annual	Yes	Yes
	Multibox	2 hr to 4 d	Yes	Yes
Monitoring	Regional trajectory	2 hr to 4 d	Yes	Yes
Land use	Regional trajectory	2 hr to 4 d	Yes	Yes
Standard setting	Regional trajectory	2 hr to 4 d	Yes	Yes
	Rollback	Weekly to annual	No	No
National (1000 km to continental U.S. spatial scale)				
Policy	Rollback	Annual	No	No
	Regional trajectory	Monthly to annual	Yes	Yes
Research and development	Regional trajectory	10 hr to 6 d	Yes	Yes
Technological assessment	Regional trajectory	Monthly to annual	Yes	Yes
Global (hemispherical to global spatial scales)				
Policy	Simple global model	Monthly to annual	Yes	Yes
Assessment	Complex global model	2 d to 2 wk	Yes	Yes
	Simple global model	Monthly to decades	Yes	Yes

Review Exercise

1. Air quality models are organized into subclasses. One model subclass is rollback. Name three others.	
2. Given the following lists of geographical scales and representative sites, match them appropriately. Geographical scales: A. site specific; B. regional; C. national; D. global Representative sizes: a. hemispherical; b. 1 to 20 kilometers; c. 1000 km to continental U.S.; d. 20 to 1000 kilometers	1. • statistical • Gaussian plume and puff • regional trajectory • box and multibox • grid, particle, global, physical
3. Given the table that summarizes model applications, give the model subclass that is recommended for use for a weekly to annual, site-specific, fuel-choice problem at a power plant (see Table 3-2).	2. A., b. 1 to 20 kilometers B., d. 20 to 1000 kilometers C., c. 1000 km to continental U.S. D., a. hemispherical
	3. rollback

Unit 4
Gaussian Point Source Atmospheric Dispersion Models

Lesson 1
Introduction to UNAMAP, Version 4

Reading Guidance

The information of availability letter that you will read as part of this lesson concerns all 21 UNAMAP models found in Version 4. The only models mentioned in the letter you should read carefully are the PTMAX, PTDIS, PTMTP, PTPLU, CRSTER, RAM, MPTER, and VALLEY. This letter shows you how the UNAMAP verions are announced.

Supplementary Reading

DOE/TIC-11223, *Handbook on Atmospheric Diffusion,* U.S. Department of Energy, 1982, chapter 4.

Lesson Goal and Objectives

Goal

To familiarize you with the purpose and general characteristics of the UNAMAP, Version 4* computer package.

Objectives

At the end of this lesson, you should be able to:

1. write the meaning of the acronym UNAMAP.
2. choose a statement that describes the purpose of UNAMAP.

*Version 5 is scheduled for release in 1983 and will add several new models to UNAMAP. All of the models discussed in this course will remain unchanged with the release of Version 5.

Introduction

In Unit 3, you read about the general characteristics of air quality models—time and space scales, frame of reference, pollutants, relationship of model to time, and treatment of turbulences and topography. You discovered that models are not easy to classify. We also discussed using models to make decisions.

Review
Time and space scales Frame of reference Pollutants Relationship of model to time Treatment of turbulence and topography

Background

The package of computerized dispersion models that U.S. EPA provides is called UNAMAP. UNAMAP is an acronym for User's Network for Applied Modeling of Air Pollution. Although not all UNAMAP models are approved, U.S. EPA-approved models have been available on computer tape since 1973. UNAMAP is provided as a public service; it is not a Federally mandated requirement. It also serves to ensure that the same models are available to all users. The Meteorology and Assessment Division (MD) of the Environmental Science Research Laboratory (ESRL) at Research Triangle Park, North Carolina, is the agency that decides which models will be on the package.

UNAMAP
User's Network for Applied Modeling of Air Pollution

Selection for UNAMAP

UNAMAP contains EPA guideline models and other state-of-the-art Gaussian dispersion techniques. Not all of the models mentioned in the *Guideline on Air Quality Models,* EPA 450/2-78-027 (Figure 4-1), are included in the UNAMAP package. Those that are excluded are generally of limited use in regulatory activities, are exceedingly complex and expensive to run (e.g., numerical models), or have undergone only limited testing.

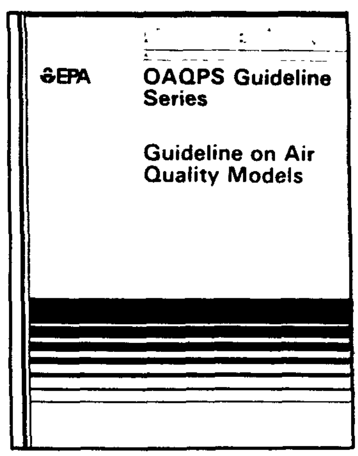


Figure 4-1. *Guideline.*

Availability

The UNAMAP, Version 4 is available without cost to certain qualified users. For example, Federal, State, and local air pollution modelers may use the package free. The Regional Meteorologist in the user's area can grant permission for obtaining the package or using the computer located in Research Triangle Park, NC. The U.S. EPA computer is a Sperry-Rand UNIVAC Series 1100 system model.

National Technical Information Service (NTIS) Springfield, Virginia

UNAMAP $840.00

Other users, such as private industry, may obtain copies of the UNAMAP tape from the National Technical Information Service (NTIS) located in Springfield, Virginia. These users must pay a fee of $840 for the complete model series. The users will receive model software that is designed to run on a UNIVAC computer. For other computer systems, changes to the software, sometimes extensive, must be made. An IBM version of the UNAMAP tape is available from HMM Associates Inc. of Waltham, MA.

The UNAMAP series is updated periodically. As newer models are created that have wider use and appeal, and other models gain popular usage, they will be added to the package.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
ENVIRONMENTAL SCIENCES RESEARCH LABORATORY
RESEARCH TRIANGLE PARK
NORTH CAROLINA 27711

April 17, 1981

Information on availability of UNAMAP (Version 4):

The Environmental Operations Branch makes available air quality dispersion models through its system UNAMAP (User's Network for Applied Modeling of Air Pollution). UNAMAP is in two forms: 1) EPA users access UNAMAP on EPA's UNIVAC 1100 computer at Research Triangle Park, N.C. 2) Users outside EPA can purchase a magnetic tape containing the FORTRAN source codes and test data from NTIS so that the specific models of interest can be installed and executed on the user's computer.

UNAMAP (Version 4) is the latest UNAMAP update and became available March 12, 1981. It contains FORTRAN source code for 21 air quality simulation models. The contents of the tape as well as brief abstracts and references are given in the attached description of UNAMAP. The tape furnished in ASCII, 9 track, 1600 bits per inch, odd parity. The following information is furnished for ordering the magnetic tape.

Tape name	UNAMAP (Version 4)
Accession number	PB 81 164 600
Price	$ 840 for North American Purchasers
	$1360 for all others
Available from:	Computer Products (703) 487-4763 National Technical Information Service U.S. Department of Commerce Springfield, VA 22161

Users Guides are furnished with each tape as well as a copy of the print-out resulting from execution of the models using the test data included on the tape.

Sincerely yours,

D. Bruce Turner

D. Bruce Turner/NOAA (919) 541-4564
Chief, Environmental Operations Branch
Meteorology and Assessment Division
Environmental Sciences Research Laboratory

Mailing address:
Chief, EOB
Mail Drop 80, EPA
RESCH TRI PK, NC 27711

* * * * * * * * * * * WHAT IS UNAMAP?* * * * * * * * * * * * * *

UNAMAP IS AN ACRONYM FOR USER'S NETWORK FOR APPLIED MODELING OF AIR POLLUTION. THIS IS A COLLECTION OF FORTRAN SOURCE CODES FOR AIR QUALITY SIMULATION MODELS (AQSM).

UNAMAP EXISTS IN TWO FORMS:

1) SOURCE CODES AND EXECUTABLES RESIDE IN EPA'S UNIVAC 1110 AT RESEARCH TRIANGLE PARK, NC. THESE PROGRAMS CAN BE READILY ACCESSED BY EPA USERS.

2) A MAGNETIC TAPE CONTAINING FORTRAN SOURCE CODES AND TEST DATA IS AVAILABLE FROM THE NATIONAL TECHNICAL INFORMATION SERVICE, U. S. DEPARTMENT OF COMMERCE, SPRINGFIELD, VA 22161. THIS TAPE HAS 23 FILES. TAPE NAME: UNAMAP (VERSION 4), ACCESSION NUMBER: PB 81 164 600, PRICE: $840.

* * * * * * * * * * * * * * *BACKGROUND* * * * * * * * * * * * * *

SINCE 1973, UNAMAP HAS SERVED AS A SOURCE FOR AQSM'S IN COMPUTER COMPATIBLE FORM. THESE MODELS INPUT EMISSION AND METEOROLOGICAL DATA TO CALCULATE PROJECTED AIR POLLUTANT CONCENTRATIONS. UNAMAP IS BASICALLY STATE-OF-THE-ART DISPERSION RESEARCH ALGORITHMS SUPPORTED BY EPA'S OFFICE OF RESEARCH AND DEVELOPMENT. AS AN ADDITIONAL SERVICE TO THE REGULATORY GROUPS IN EPA AND TO THOSE TRYING TO CONFORM TO REGULATIONS, UNAMAP CONTAINS "GUIDELINE MODELS." GUIDELINE MODELS ARE THOSE IDENTIFIED BY EPA'S OFFICE OF AIR QUALITY PLANNING AND STANDARDS IN "OAQPS GUIDELINE SERIES, GUIDELINE ON AIR QUALITY MODELS, EPA-450/2-78-027, OAQPS NO. 1.2-080, APRIL 1978. (GUIDELINES HAVE BEEN PROPOSED AND PRESENTED AT THREE PUBLIC MEETINGS IN WASHINGTON, SEATTLE, AND CHICAGO IN OCTOBER 1980. BASED ON COMMENTS RECEIVED AT THESE MEETINGS AND SUBMITTED IN WRITING TO THE DOCKET BY DECEMBER 1, 1980, REVISIONS WILL BE MADE. THE REVISED PROPOSED GUIDELINES WILL BE PRESENTED AND DISCUSSED AT A PUBLIC MEETING.)

IN THE PAST SOME PERSONS HAVE TENDED TO EQUATE UNAMAP WITH GUIDELINE MODELS. OUR INTENTION IS THAT UNAMAP WILL INCLUDE GUIDELINE MODELS, IN SO FAR AS IS POSSIBLE, BUT THAT UNAMAP PRIMARILY REPRESENTS STATE-OF-THE-ART DISPERSION RESEARCH ALGORITHMS. (SOME OF THESE MODELS MAY EVENTUALLY BECOME CANDIDATES FOR GUIDELINE STATUS.)

VERSION 3 OF UNAMAP WAS MADE AVAILABLE IN MARCH 1978. IT CONTAINED 11 AQSM'S. THREE CHANGES WERE ISSUED TO PURCHASERS OF UNAMAP (VERSION 3):

CHANGE 1	23 AUGUST 1978
CHANGE 2	5 JULY 1979
CHANGE 3	16 AUGUST 1979

UNAMAP (VERSION 4) RELEASED DECEMBER 1980.

IT IS ANTICIPATED THAT UPON AVAILABILITY OF THE 1981 MODELING GUIDELINES, THAT THE SECTION ON GUIDELINE MODELS WILL BE REVISED AND UNAMAP (VERSION 5) WILL BE ISSUED. THIS IS CURRENTLY SCHEDULED FOR DECEMBER 1981.

* * * * * * * * * * * CHANGES TO UNAMAP * * * * * * * * * *

SINCE IT IS RARE FOR A PIECE OF COMPUTER CODE TO BE COMPLETELY ERROR FREE UNDER ALL POSSIBLE COMBINATIONS OF ACCEPTABLE INPUT, ERRORS ARE DETECTED OR BROUGHT TO OUR ATTENTION. WE TRY TO BRING TO THE ATTENTION OF USERS OF UNAMAP THE CORRECTIONS TO RESOLVE SUCH ERRORS.

* * * * * * * * * * DISCUSSION OF UNAMAP SUPPORT * * * * * * * * * *

IN THE PAST THE ENVIRONMENTAL OPERATIONS BRANCH HAS SUPPORTED ALL FORTRAN CODES ON UNAMAP FROM THE STANDPOINT OF HAVING AT LEAST ONE INDIVIDUAL IN THE BRANCH FAMILIAR WITH THE LINES OF PROGRAM CODE AND THEIR FUNCTION AND HAVE MADE CODING CHANGES AS REQUIRED TO CORRECT THE CODE AS PROBLEMS OCCUR. WE HAVE ALSO TRIED TO PROVIDE LIAISON WITH USERS IN ATTEMPTING TO ADVISE ON THE MOST APPROPRIATE MODEL (IF ANY) TO USE FOR GIVEN SITUATIONS IN SO FAR AS THOSE SITUATIONS CAN BE ADEQUATELY DESCRIBED IN A PHONE CONVERSATION OF REASONABLE LENGTH.

THERE ARE THREE PROFESSIONALS ON OUR STAFF THAT IN ADDITION TO OTHER RESEARCH DUTIES ASSIST ON UNAMAP. THESE PERSONS ARE BRUCE TURNER, WILLIAM PETERSEN, AND JOHN IRWIN. WE HAVE BEEN FORTUNATE TO HAVE A PART-TIME STUDENT EMPLOYEE, THOMAS PIERCE, OVER THE LAST YEAR AND A HALF WHO HAS ALSO BEEN OF GREAT ASSISTANCE ON UNAMAP.

THE OFFICE OF AIR QUALITY PLANNING AND STANDARDS HAS GIVEN ASSISTANCE IN SUPPORT OF UNAMAP ESPECIALLY IN REVISING AND MAINTAINING CRSTER AND VALLEY. WE ARE GRATEFUL TO JEROME MERSCH AND EDWARD BURT FOR THAT SUPPORT.

* * * UNAMAP (VERSION 4) - CONTENTS * * *

	TOTAL LINES OF SOURCE CODE	NUMBER OF SUB PROGS.	UNIVAC 1100 CORE REQUIRED	UNIVAC 1100 COST OF TEST	NUMBER OUTPUT PAGES OF TEST
UNAMAP DESCRIPTION					
SECTION 1. MODELS FOR EVALUATION.					
COMPLEXII	2811	8	51K	$ 0.40	11
COMPLEXI	2794	8	50K	$ 0.40	11
BLP	2062	21	20K	$ 0.75	9
POSTBLP	929	5	17K	$ 0.43	14
SECTION 2. GUIDELINE MODELS (1978).					
RAM	4547	14	64K	$ 1.14	20
RAMMET	332	0			
CRSTER	1728	4	28K	$ 2.31	23
CRSMET	422	0			
CDM	1313	5	20K	$ 5.54	10
CDMQC	1988	11	48K	$10.14	23
APRAC	2015	19	32K	$ 1.11	3
HIWAY	1242	6	11K	$ 0.92	2
HIWAYI	1303	6			
VALLEY	1006	2	14K	$ 0.24	12
TEM8	3778	12	39K	$ 0.36	9
TCM2	2004	8	41K	$ 0.55	11
SECTION 3. MODELS PROPOSED SEP 80 FOR 81 GUIDELINES.					
PAL	3484	18	43K	$ 1.13	6
PTPLU	957	5	12K	$ 0.38	2
MPTER	2479	7	48K	$ 0.32	3
HIWAY2	1298	4	8K	$ 1.11	2
HIWAY2I	1299	4			
ISCST	2756	9	65K	$ 8.30	36
ISCSMET	332	0			
ISCLT	3503	15	EXP1 67K	$10.35	19
			EXP2 69K	$ 8.51	17
SECTION 4. MODELS OF HISTORICAL INTEREST.					
PTMAX	460	2	9K	$ 0.13	2
PTDIS	625	3	9K	$ 0.22	6
PTMTP	661	3	10K	$ 0.16	4
PTMAXI	461	2			
PTDISI	644	3			
PTMTPI	673	3			
SECTION 5. MISCELLANEOUS.					
TPHI5	251	1			
TPRN25	318	1			

	LINES OF DATA
SET RANDOM NUMBERS	366
ONE YEAR SURFACE DATA (FOR INPUT TO MET PREPROCESSOR)	8784
ONE YEAR MIXING HEIGHT DATA (FOR INPUT TO MET PREPROCESSOR)	368
PROGRAM TO TRANSLATE MET DATA TO UNFORMATTED	
ONE YEAR MET DATA OUTPUT FROM MET PROCESSOR (FORMATTED)	8785

WE HAVE ALSO HAD ASSISTANCE FROM THE DATA MANAGEMENT AND SYSTEMS ANALYSIS SECTION OF THE ATMOSPHERIC MODELING AND ASSESSMENT BRANCH. SPECIFICALLY JOAN NOVAK, CHIEF OF THAT SECTION, ADRIAN BUSSE, AND ALFREIDA RANKINS HAVE ASSISTED CONSIDERABLY.

WITH THE ADDITION OF A NUMBER OF MODELS ON VERSION 4 WITH NO CHANGES IN STAFF AND WITH EXTRAMURAL RESOURCES DECREASING MARKEDLY (NOT INCLUDING THE EFFECTS OF INFLATION), WE REGRET TO SAY THAT WE WILL NOT BE ABLE TO SUPPORT ALL MODELS UNIFORMLY. IN FACT, SOME OF THE MODELS ARE PLACED IN UNAMAP FOR YOUR EXAMINATION WITH NO SUPPORT.

* * * * * * * * * * UNAMAP PROGRAM DESCRIPTIONS * * * * * * * * *

NOTE!

SERIES 600 EPA PUBLICATIONS ARE AVAILABLE FROM:
ENVIRONMENTAL RESEARCH INFORMATION CENTER
OFFICE OF RESEARCH AND DEVELOPMENT
ENVIRONMENTAL PROTECTION AGENCY
CINCINNATI, OH 45268
PHONE: COMM'L (513)684-7562 FTS 684-7562

SERIES 450 EPA PUBLICATIONS ARE AVAILABLE FROM:
LIBRARY
MAIL DROP 35, EPA
RESRCH TRI PK, NC 27711
PHONE: COMM'L (919)541-2777 FTS 629-2777

* *

COMPLEX II

COMPLEX II IS A MULTIPLE POINT SOURCE CODE WITH TERRAIN ADJUSTMENT. THE MODEL SPECIFICATIONS FOR TESTING WERE SUGGESTED BY TEAM "B" ON COMPLEX TERRAIN AT THE REGIONAL WORKSHOP ON AIR QUALITY MODELING IN CHICAGO IN FEBRUARY 1980. IT IS A SEQUENTIAL MODEL UTILIZING HOURLY METEOROLOGICAL INPUT AND ASSUMES THAT HOURLY AVERAGED PLUMES HAVE NORMAL DISTRIBUTIONS IN BOTH THE HORIZONTAL AND VERTICAL.

THERE IS NO USERS GUIDE FOR COMPLEX II AND NO PLANS TO DEVELOP ANY AS OF DEC 80.

* *

COMPLEX I

COMPLEX I IS A MULTIPLE POINT SOURCE CODE WITH TERRAIN ADJUSTMENT. THE MODEL SPECIFICATIONS FOR TESTING WERE SUGGESTED BY TEAM "B" ON COMPLEX TERRAIN AT THE REGIONAL WORKSHOP ON AIR QUALITY MODELING IN CHICAGO IN FEBRUARY 1980. IT IS A SEQUENTIAL MODEL UTILIZING HOURLY METEOROLOGICAL INPUT. IT ASSUMES A NORMAL DISTRIBUTION IN THE VERTICAL AND A UNIFORM DISTRIBUTION ACROSS A 22.5 DEGREE SECTOR: THEREFORE IT REPRESENTS A SEQUENTIAL MODELING BRIDGE BETWEEN VALLEY AND COMPLEX II.

THERE IS NO USERS GUIDE FOR COMPLEX I AND NO PLANS TO DEVELOP ANY AS OF DEC 80.

* *

BLP

BLP (BUOYANT LINE AND POINT SOURCE DISPERSION MODEL) IS A GAUSSIAN PLUME DISPERSION MODEL DESIGNED TO HANDLE UNIQUE MODELING PROBLEMS ASSOCIATED WITH ALUMINUM REDUCTION PLANTS, AND OTHER INDUSTRIAL SOURCES WHERE PLUME RISE AND DOWNWASH EFFECTS FROM STATIONARY LINE SOURCES ARE IMPORTANT.

SCHULMAN, LLOYD L., AND JOSEPH S. SCIRE. "BUOYANT LINE AND POINT SOURCE (BLP) DISPERSION MODEL USER'S GUIDE." DOCUMENT P-7304B. ENVIRONMENTAL RESEARCH AND TECHNOLOGY, INC., CONCORD, MA. (NTIS ACCESSION NUMBER PB 81 164 642.)

SCHULMAN, LLOYD L., AND JOSEPH S. SCIRE. "DEVELOPMENT OF AN AIR QUALITY DISPERSION MODEL FOR ALUMINUM REDUCTION PLANTS." DOCUMENT P-7304A. ENVIRONMENTAL RESEARCH AND TECHNOLOGY, INC., CONCORD, MA (NTIS ACCESSION NUMBER PB 81 164 634.)

* *

RAM

GAUSSIAN-PLUME MULTIPLE-SOURCE AIR QUALITY ALGORITHM. THIS SHORT-TERM GAUSSIAN STEADY-STATE ALGORITHM ESTIMATES CONCENTRATIONS OF STABLE POLLUTANTS FROM URBAN POINT AND AREA SOURCES. HOURLY METEOROLOGICAL DATA ARE USED. HOURLY CONCENTRATIONS AND AVERAGES OVER A NUMBER OF HOURS CAN BE ESTIMATED. BRIGGS PLUME RISE IS USED. PASQUILL-GIFFORD DISPERSION EQUATIONS WITH DISPERSION PARAMETERS THOUGHT TO BE VALID FOR URBAN AREAS ARE USED. CONCENTRATIONS FROM AREA SOURCES ARE DETERMINED USING THE METHOD OF HANNA, THAT IS, SOURCES DIRECTLY UPWIND ARE CONSIDERED REPRESENTATIVE OF AREA SOURCE EMISSIONS AFFECTING THE RECEPTOR. SPECIAL FEATURES INCLUDE DETERMINATION OF RECEPTOR LOCATIONS DOWNWIND OF SIGNIFICANT SOURCES AND DETERMINATION OF LOCATIONS OF UNIFORMLY SPACED RECEPTORS TO ENSURE GOOD AREA COVERAGE WITH A MINIMUM NUMBER OF RECEPTORS.

TURNER, D. BRUCE, AND NOVAK, JOAN HRENKO, 1978: USER'S GUIDE FOR RAM, VOL. I. ALGORITHM DESCRIPTION AND USE. EPA-600/8-78-016A (NTIS ACCESSION NUMBER PB 294 791), VOL. II. DATA PREPARATION AND LISTINGS. EPA-600/8-78-016B (NTIS ACCESSION NUMBER PB 294 792.) U.S. ENVIRONMENTAL PROTECTION AGENCY, RESEARCH TRIANGLE PARK, NC. (NOVEMBER 1978).

NOTE: RAM HAS BEEN REVISED IN 1980. BE SURE TO EXAMINE INFORMATION IN THE SOURCE CODE TO PREPARE RUNSTREAMS ETC. THE REVISION IS FOR ADDED USER CONVENIENCE AND OPTIONS. ALL CALCULATIONS PRODUCED WITH THE ORIGINAL RAM CAN BE REPRODUCED WITH THE CURRENT RAM WITH NO CHANGE IN NUMERICAL RESULTS.

* *

CRSTER

THIS ALGORITHM ESTIMATES GROUND-LEVEL CONCENTRATIONS RESULTING FROM UP TO 19 COLOCATED ELEVATED STACK EMISSIONS FOR AN ENTIRE YEAR AND PRINTS OUT THE HIGHEST AND SECOND-HIGHEST 1-HR, 3-HR, AND 24-HR CONCENTRATIONS AS WELL AS THE ANNUAL MEAN CONCENTRATIONS AT A SET OF 180 RECEPTORS (5 DISTANCES BY 36 AZIMUTHS). THE ALGORITHM IS BASED ON A MODIFIED FORM OF THE STEADY-STATE GAUSSIAN PLUME EQUATION WHICH USES EMPIRICAL DISPERSION COEFFICIENTS AND INCLUDES ADJUSTMENTS FOR PLUME RISE AND LIMITED MIXING. TERRAIN ADJUSTMENTS ARE MADE AS LONG AS THE SURROUNDING TERRAIN IS PHYSICALLY LOWER THAN THE LOWEST STACK HEIGHT INPUT. POLLUTANT CONCENTRATIONS FOR EACH AVERAGING TIME ARE COMPUTED FOR DISCRETE, NON-OVERLAPPING TIME PERIODS (NO RUNNING AVERAGES ARE COMPUTED) USING MEASURED HOURLY VALUES OF WIND SPEED AND DIRECTION, AND ESTIMATED HOURLY VALUES OF ATMOSPHERIC STABILITY AND MIXING HEIGHT.

MONITORING AND DATA ANALYSIS DIVISION, 1977: USER'S MANUAL FOR SINGLE-SOURCE (CRSTER) MODEL. U. S. ENVIRONMENTAL PROTECTION AGENCY. RESEARCH TRIANGLE PARK, NC. EPA-450/2-77-013. (NTIS ACCESSION NUMBER PB 271-360).

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CDM

THE CLIMATOLOGICAL DISPERSION MODEL DETERMINES LONG TERM (SEASONAL OR ANNUAL) QUASI-STABLE POLLUTANT CONCENTRATIONS AT ANY GROUND LEVEL RECEPTOR USING AVERAGE EMISSION RATES FROM POINT AND AREA SOURCES AND A JOINT FREQUENCY DISTRIBUTION OF WIND DIRECTION, WIND SPEED, AND STABILITY FOR THE SAME PERIOD.

BUSSE, ADRIAN D., AND ZIMMERMAN, J.R., 1973: USER'S GUIDE FOR THE CLIMATOLOGICAL DISPERSION MODEL. U.S. ENVIRONMENTAL PROTECTION AGENCY. RESEARCH TRIANGLE PARK, NC. ENVIRONMENTAL MONITORING SERIES, EPA-R4-73-024, 131 P. (NTIS ACCESSION NUMBER PB 227-346).

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CDMQC

THIS ALGORITHM IS THE CLIMATOLOGICAL DISPERSION MODEL (CDM) ALTERED TO PROVIDE IMPLEMENTATION: OF CALIBRATION, OF INDIVIDUAL POINT AND AREA SOURCE CONTRIBUTION LISTS, AND OF AVERAGING TIME TRANSFORMATIONS. THE BASIC ALGORITHMS TO CALCULATE POLLUTANT CONCENTRATIONS USED IN THE CDM HAVE NOT BEEN MODIFIED, AND RESULTS OBTAINED USING CDM MAY BE REPRODUCED USING THE CDMQC.

BRUBAKER, KENNETH L., BROWN, POLLY, AND CIRILLO, RICHARD R., 1977: ADDENDUM TO USER'S GUIDE FOR CLIMATOLOGICAL DISPERSION MODEL. PREPARED BY ARGONNE NATIONAL LABORATORY FOR THE U.S. ENVIRONMENTAL PROCTECTION AGENCY, RESEARCH TRIANGLE PARK, NC. EPA-450/3-77-015. (NTIS ACCESSION NUMBER PB 274-040).

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APRAC

STANFORD RESEARCH INSTITUTE'S URBAN CARBON MONOXIDE MODEL COMPUTES HOURLY AVERAGES FOR ANY URBAN LOCATION. REQUIRES AN EXTENSIVE TRAFFIC INVENTORY FOR THE CITY OF INTEREST. REQUIREMENTS AND TECHNICAL DETAILS ARE DOCUMENTED IN:

USER'S MANUAL FOR THE APRAC-1A URBAN DIFFUSION MODEL COMPUTER PROGRAM (NTIS ACCESSION NUMBER PB 213-091.) ADDITIONAL INFORMATION IS AVAILABLE ON APRAC FROM:

A PRACTICAL, MULTIPURPOSE URBAN DIFFUSION MODEL FOR CARBON MONOXIDE (NTIS ACCESSION NUMBER PB 196-003).

FIELD STUDY FOR INITIAL EVALUATION OF AN URBAN DIFFUSION MODEL FOR CARBON MONOXIDE (NTIS ACCESSION NUMBER PB 203-469).

EVALUATION OF THE APRAC-1A URBAN DIFFUSION MODEL FOR CARBON MONOXIDE (NTIS ACCESSION NUMBER PB 210-813.)

DABBERDT, WALTER F.; LUDWIG, F.L.; AND JOHNSON, WARREN B., JR., 1973: VALIDATION AND APPLICATIONS OF AN URBAN DIFFUSION MODEL FOR VEHICULAR POLLUTANTS, ATMOS. ENVIRON., 7, 603-618.

JOHNSON, W.B.; LUDWIG, F.L.; DABBERDT, W.F.; AND ALLEN, R.J., 1973: AN URBAN DIFFUSION SIMULATION MODEL FOR CARBON MONOXIDE. J. AIR POLL. CONTROL ASSOC. 23, 6, 490-498.

* *

HIWAY

COMPUTES THE HOURLY CONCENTRATIONS OF NON-REACTIVE POLLUTANTS DOWNWIND OF ROADWAYS. IT IS APPLICABLE FOR UNIFORM WIND CONDITIONS AND LEVEL TERRAIN. ALTHOUGH BEST SUITED FOR AT-GRADE HIGHWAYS, IT CAN ALSO BE APPLIED TO DEPRESSED HIGHWAYS (CUT SECTIONS).

ZIMMERMAN, J.R.: AND THOMPSON, R.S., 1975: USER'S GUIDE FOR HIWAY: A HIGHWAY AIR POLLUTION MODEL. U.S. ENVIRONMENTAL PROTECTION AGENCY, RESEARCH TRIANGLE PARK, NC. ENVIRONMENTAL MONITORING SERIES, EPA-650/4-74-008, 59 P. (NTIS ACCESSION NUMBER PB 239-944).

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VALLEY

THIS ALGORITHM IS A STEADY-STATE, UNIVARIATE GAUSSIAN PLUME DISPERSION ALGORITHM DESIGNED FOR ESTIMATING EITHER 24-HOUR OR ANNUAL CONCENTRATIONS RESULTING FROM EMISSIONS FROM UP TO 50 (TOTAL) POINT AND AREA SOURCES. CALCULATIONS OF GROUND-LEVEL POLLUTANT CONCENTRATIONS ARE MADE FOR EACH FREQUENCY DESIGNATED IN IN ARRAY DEFINED BY SIX STABILITIES, 16 WIND DIRECTIONS, AND SIX WIND SPEEDS FOR 112 PROGRAM-DESIGNED RECEPTOR SITES ON A RADIAL GRID OF VARIABLE SCALE. EMPIRICAL DISPERSION COEFFICIENTS ARE USED AND INCLUDE ADJUSTMENTS FOR PLUME RISE AND LIMITED MIXING. PLUME HEIGHT IS ADJUSTED ACCORDING TO TERRAIN ELEVATIONS AND STABILITY CLASSES.

BURT, EDWARD W., 1977: VALLEY MODEL USER'S GUIDE, U.S. ENVIRONMENTAL PROTECTION AGENCY, RESEARCH TRIANGLE PARK, NC, EPA-450/2-77-018. (NTIS ACCESSION NUMBER PB 274-054).

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TEM

TEM (TEXAS EPISODIC MODEL) IS A SHORT-TERM, STEADY-STATE GUASSIAN PLUME MODEL FOR DETERMINING SHORT-TERM CONCENTRATIONS OF NONE-REACTIVE POLLUTANTS.

STAFF OF THE TEXAS AIR CONTROL BOARD. USER'S GUIDE TO THE TEXAS EPISODIC MODEL. TEXAS AIR CONTROL BOARD, PERMITS SECTION, 6330 HIGHWAY 290 EAST, AUSTIN, TEXAS 78723. (NTIS ACCESSION NUMBER PB 80-227 572)

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TCM

TCM (TEXAS CLIMATOLOGICAL MODEL) IS A CLIMATOLOGICAL STEADY-STATE GAUSSIAN PLUME MODEL FOR DETERMINING LONG-TERM (SEASONAL OR ANNUAL ARITHMETIC) AVERAGE POLLUTANT CONCENTRATIONS OF NON-REACTIVE POLLUTANTS.

STAFF OF THE TEXAS AIR CONTROL BOARD, USER'S GUIDE TO THE TEXAS CLIMATOLOGICAL MODEL (TCM). TEXAS AIR CONTROL BOARD, PERMITS SECTION, 6330 HIGHWAY 290 EAST, AUSTIN, TX 78723 (NTIS ACCESSION NUMBER PB 81 164 626.)

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PAL

POINT, AREA, LINE SOURCE ALGORITHM. THIS SHORT-TERM GAUSSIAN STEADY-STATE ALGORITHM ESTIMATES CONCENTRATIONS OF STABLE POLLUTANTS FROM POINT, AREA, AND LINE SOURCES. COMPUTATIONS FROM AREA SOURCES INCLUDE EFFECTS OF THE EDGE OF THE SOURCE. LINE SOURCE COMPUTATIONS CAN INCLUDE EFFECTS FROM A VARIABLE EMISSION RATE ALONG THE SOURCE. THE ALGORITHM IS NOT INTENDED FOR APPLICATION TO ENTIRE URBAN AREAS BUT FOR SMALLER SCALE ANALYSIS OF SUCH SOURCES AS SHOPPING CENTERS, AIRPORTS, AND SINGLE PLANTS. HOURLY CONCENTRATIONS ARE ESTIMATED AND AVERAGE CONCENTRATIONS FROM 1 HOUR TO 24 HOURS CAN BE OBTAINED.

PETERSEN, WILLIAM B., 1978: USER'S GUIDE FOR PAL - A GAUSSIAN-PLUME ALGORITHM FOR POINT, AREA, AND LINE SOURCES. U.S. ENVIRONMENTAL PROTECTION AGENCY, RESEARCH TRIANGLE PARK, N.C., ENVIRONMENTAL MONITORING SERIES EPA-600/4-78-013 (NTIS ACCESSION NUMBER PB 281-306).

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PTPLU

PTPLU IS A POINT SOURCE DISPERSION GAUSSIAN SCREENING MODEL FOR ESTIMATING MAXIMUM SURFACE CONCENTRATIONS FOR 1-HOUR PERIODS. PTPLU IS BASED UPON BRIGGS PLUME RISE METHODS AND PASQUILL-GIFFORD DISPERSION COEFFICIENTS AS OUTLINED IN THE WORKBOOK OF ATMOSPHERIC DISPERSION ESTIMATES. PTPLU IS AN ADAPTATION AND IMPROVEMENT OF PTMAX WHICH ALLOWS FOR WIND PROFILE EXPONENTS AND OTHER OPTIONAL CALCULATIONS SUCH AS BUOYANCY INDUCED DISPERSION, STACK DOWNWASH, AND GRADUAL PLUME RISE. PTPLU PRODUCES AN ANALYSIS OF CONCENTRATION AS A FUNCTION OF WIND SPEED AND STABILITY CLASS FOR BOTH WIND SPEEDS CONSTANT WITH HEIGHT AND WIND SPEEDS INCREASING WITH HEIGHT. USE OF THE EXTRAPOLATED WIND SPEEDS AND THE OPTIONS ALLOWS THE MODEL USER A MORE ACCURATE SELECTION OF DISTANCES TO MAXIMUM CONCENTRATION.

THERE IS NO USER'S GUIDE AVAILABLE FOR PTPLU. THE USER IS REFERRED TO THE SOURCE CODE FOR INPUT FORMATS, ETC.

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MPTER

MPTER IS A MULTIPLE POINT-SOURCE GAUSSIAN MODEL WITH OPTIONAL TERRAIN ADJUSTMENTS. MPTER ESTIMATES CONCENTRATIONS ON AN HOUR-BY-HOUR BASIS FOR RELATIVELY INERT POLLUTANTS (I.E., SO2 AND TSP). MPTER USES PASQUILL-GIFFORD DISPERSION PARAMETERS AND BRIGGS PLUME RISE METHODS TO CALCULATE THE SPREADING AND THE RISE OF PLUMES. THE MODEL IS MOST APPLICABLE FOR SOURCE-RECEPTOR DISTANCES LESS THAN 10 KILOMETERS AND FOR LOCATIONS WITH LEVEL OR GENTLY ROLLING TERRAIN. TERRAIN ADJUSTMENTS ARE RESTRICTED TO RECEPTORS WHOSE ELEVATION IS NO HIGHER THAN THE LOWEST STACK TOP. IN ADDITION TO TERRAIN ADJUSTMENTS, OPTIONS ARE ALSO AVAILABLE FOR WIND PROFILE EXPONENTS, BUOYANCY INDUCED DISPERSION, GRADUAL PLUME RISE, STACK DOWNWASH, AND PLUME HALF-LIFE.

PIERCE, T. E. AND TURNER, D. B., 1980: USER'S GUIDE FOR MPTER: A MULTIPLE POINT GAUSSIAN DISPERSION ALGORITHM WITH OPTIONAL TERRAIN ADJUSTMENT. EPA-600/8-80-016, U.S. ENVIRONMENTAL PROTECTION AGENCY, RESEARCH TRIANGLE PARK, NC. 239 PP.

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HIWAY2

HIWAY2 IS A BATCH AND INTERACTIVE PROGRAM WHICH COMPUTES THE HOURLY CONCENTRATIONS OF NON-REACTIVE POLLUTANTS DOWNWIND OF ROADWAYS. IT IS APPLICABLE FOR UNIFORM WIND CONDITIONS AND LEVEL TERRAIN. ALTHOUGH BEST SUITED FOR AT-GRADE HIGHWAYS, IT CAN ALSO BE APPLIED TO DEPRESSED HIGHWAYS (CUT SECTIONS). HIWAY2 IS INTENDED AS AN UPDATE TO THE HIWAY MODEL.

PETERSEN, W. B., 1980. USER'S GUIDE FOR HIWAY2: A HIGHWAY AIR POLLUTION MODEL. U.S. ENVIRONMENTAL PROTECTION AGENCY, RESEARCH TRIANGLE PARK, NC., EPA-600/8-80-018,70 P.

RAO, S. T. AND M. T. KEENAN, 1980: SUGGESTIONS FOR IMPROVEMENT OF THE EPA HIWAY MODEL. JAPCA, 30, 6, pp 247-256.

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ISCST

THE INDUSTRIAL SOURCE COMPLEX SHORT TERM MODEL IS A STEADY-STATE GAUSSIAN PLUME MODEL WHICH CAN BE USED TO ASSESS POLLUTANT CONCENTRATIONS FROM A WIDE VARIETY OF SOURCES ASSOCIATED WITH AN INDUSTRIAL SOURCE COMPLEX. THIS MODEL CAN ACCOUNT FOR SETTLING AND DRY DEPOSITION OF PARTICULATES, DOWNWASH, AREA, LINE AND VOLUME SOURCES, PLUME RISE AS A FUNCTION OF DOWNWIND DISTANCE, SEPARATION OF POINT SOURCES, AND LIMITED TERRAIN ADJUSTMENT. AVERAGE CONCENTRATION OR TOTAL DEPOSITION MAY BE CALCULATED IN 1-, 2-, 3-, 4-, 6-, 8-, 12- AND/OR 24-HOUR TIME PERIODS. AN 'N' -DAY AVERAGE CONCENTRATION (OR TOTAL DEPOSITION) OR AN AVERAGE CONCENTRATION (OR TOTAL DEPOSITION) OVER THE TOTAL NUMBER OF HOURS MAY ALSO BE COMPUTED.

BOWERS, J. F., J. R. BJORKLUND AND C. S. CHENEY. "INDUSTRIAL SOURCE COMPLEX (ISC) DISPERSION MODEL USER'S GUIDE, VOLUMES 1 AND 2." PUBLICATION NOS. EPA-450/4-79-030,031 (NTIS PB-80-133 044, 133 051), OFFICE OF AIR QUALITY PLANNING AND STANDARDS, U. S. ENVIRONMENTAL PROTECTION AGENCY, RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711, DECEMBER 1979.

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ISCLT

THE INDUSTRIAL SOURCE COMPLEX LONG TERM MODEL IS A STEADY-STATE GAUSSIAN PLUME MODEL WHICH CAN BE USED TO ASSESS POLLUTANT CONCENTRATIONS FROM A WIDE VARIETY OF SOURCES ASSOCIATED WITH AN INDUSTRIAL SOURCE COMPLEX. THIS MODEL CAN ACCOUNT FOR SETTLING AND DRY DEPOSITION OF PARTICULATES, DOWNWASH, AREA, LINE AND VOLUME SOURCES, PLUME RISE AS A FUNCTION OF DOWNWIND DISTANCE, SEPARATION OF POINT SOURCES, AND LIMITED TERRAIN ADJUSTMENT.

ISCLT IS DESIGNED TO CALCULATE THE AVERAGE SEASONAL AND/OR ANNUAL GROUND LEVEL CONCENTRATION OR TOTAL DEPOSITION FROM MULTIPLE CONTINUOUS POINT, VOLUME AND/OR AREA SOURCES. PROVISION IS MADE FOR SPECIAL DISCRETE X, Y RECEPTOR POINTS THAT MAY CORRESPOND TO SAMPLER SITES, POINTS OF MAXIMA OR SPECIAL POINTS OF INTEREST. SOURCES CAN BE POSITIONED ANYWHERE RELATIVE TO THE GRID SYSTEM.

BOWERS, J. F., J. R. BJORKLUND AND C. S. CHENEY. "INDUSTRIAL SOURCE COMPLEX (ISC) DISPERSION MODEL USER'S GUIDE, VOLUMES 1 AND 2." PUBLICATION NOS. EPA-450/4-79-030,031 (NTIS PB-80-133 044, 133 051), OFFICE OF AIR QUALITY PLANNING AND STANDARDS, U. S. ENVIRONMENTAL PROTECTION AGENCY, RESEARCH TRIANGLE PARK, NORTH CAROLINA 27711, DECEMBER 1979.

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PTMAX

PERFORMS AN ANALYSIS OF THE MAXIMUM SHORT-TERM CONCENTRATIONS FROM A SINGLE POINT SOURCE AS A FUNCTION OF STABILITY AND WIND SPEED. THE FINAL PLUME HEIGHT IS USED FOR EACH COMPUTATION. USES BRIGGS PLUME RISE METHODS AND PASQUILL-GIFFORD DISPERSION METHODS AS GIVEN IN EPA'S AP-26, "WORKBOOK OF ATMOSPHERIC DISPERSION ESTIMATES," TO ESTIMATE HOURLY CONCENTRATIONS FOR STABLE POLLUTANTS.

TURNER, D.B.: AND BUSSE, A.D., 1973: USER'S GUIDE TO THE INTERACTIVE VERSIONS OF THREE POINT SOURCE DISPERSION PROGRAMS: *PTMAX, PTDIS, AND PTMTP. PRELIMINARY DRAFT*, METEOROLOGY LABORATORY, U.S. ENVIRONMENTAL PROTECTION AGENCY, RESEARCH TRIANGLE PARK, NC. 27711

* *

PTDIS

ESTIMATES SHORT-TERM CONCENTRATIONS DIRECTLY DOWNWIND OF A POINT SOURCE AT DISTANCES SPECIFIED BY THE USER. THE EFFECT OF LIMITING VERTICAL DISPERSION BY A MIXING HEIGHT CAN BE INCLUDED AND GRADUAL PLUME RISE TO THE POINT OF FINAL RISE IS ALSO CONSIDERED. AN OPTION ALLOWS THE CALCULATION OF ISOPLETH HALF-WIDTHS FOR SPECIFIC CONCENTRATIONS AT EACH DOWNWIND DISTANCE. USES BRIGGS PLUME RISE METHODS AND PASQUILL-GIFFORD DISPERSION METHODS AS GIVEN IN EPA'S AP-26, "WORKBOOK OF ATMOSPHERIC DISPERSION ESTIMATES," TO ESTIMATE HOURLY CONCENTRATIONS FOR STABLE POLLUTANTS.

TURNER, D.B.AND BUSSE, A.D., 1973: USER'S GUIDE TO THE INTERACTIVE VERSIONS OF THREE POINT SOURCE DISPERSION PROGRAMS: PTMAX, PTDIS, AND PTMTP. PRELIMINARY DRAFT, METEOROLOGY LABORATORY, U.S. ENVIRONMENTAL PROTECTION AGENCY, RESEARCH TRIANGLE PARK, NC 27711.

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PTMTP

ESTIMATES FOR A NUMBER OF ARBITRARILY LOCATED RECEPTOR POINTS AT OR ABOVE GROUND-LEVEL, THE CONCENTRATION FROM A NUMBER OF POINT SOURCES. PLUME RISE IS DETERMINED FOR EACH SOURCE. DOWNWIND AND CROSSWIND DISTANCES ARE DETERMINED FOR EACH SOURCE-RECEPTOR PAIR. CONCENTRATIONS AT A RECEPTOR FROM VARIOUS SOURCES ARE ASSUMED ADDITIVE. HOURLY METEOROLOGICAL DATA ARE USED: BOTH HOURLY CONCENTRATIONS AND AVERAGES OVER ANY AVERAGING TIME FROM ONE TO 24 HOURS CAN BE OBTAINED. USES BRIGGS PLUME RISE METHODS AND PASQUILL-GIFFORD DISPERSION METHODS AS GIVEN IN EPA'S AP-26, "WORKBOOK OF ATMOSPHERIC DISPERSION ESTIMATES," TO ESTIMATE HOURLY CONCENTRATIONS FOR STABLE POLLUTANTS.

TURNER, D.B.: AND BUSSE, A.D., 1973: USER'S GUIDE TO THE INTERACTIVE VERSIONS OF THREE POINT SOURCE DISPERSION PROGRAMS: PTMAX, PTDIS, AND PTMTP. PRELIMINARY DRAFT, METEOROLOGY LABORATORY, U.S. ENVIRONMENTAL PROTECTION AGENCY, RESEARCH TRIANGLE PARK, NC 27711

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TPHI5

TPHI5 (TURNER AND PIERCE'S HIGH-FIVE PROGRAM) IS A PERIPHERAL PROGRAM WHICH READS DATA OFF AN HOURLY CONC FILE (OUTPUT FROM RAM, CRSTER, OR MPTER) AND TABULATES END TO END AVERAGE CONCENTRATIONS FOR VARIOUS AVG TIMES (UP TO 5) FOR THE NUMBER OF STATIONS CONTAINED ON THE TAPE/DISK FILE ASSIGNED TO THE RUNSTREAM.

THERE IS CURRENTLY NO USER'S GUIDE FOR TPHI5. USERS ARE REFERRED TO A LISTING OF THE SOURCE PROGRAM FOR INFORMATION.

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TPRN25

TPRN25 IS A PERIPHERAL PROGRAM DESIGNED TO READ CONCS.OFF A DISK/TAPE FILE AND DETERMINE RUNNING AVERAGES FOR FOUR OR FIVE AVG.TIMES. THE USER DESIGNATES THE FIFTH AVERAGING TIME AND THE STATION NUMBERS (UP TO 50). THE OUTPUT THEN CONSISTS OF TABLES OF THE 25 HIGHEST CONCENTRATIONS FOR EACH AVG TIME AND RECEPTOR.

THERE IS CURRENTLY NO USER'S GUIDE FOR TPRN25. USERS ARE REFERRED TO A LISTING OF THE SOURCE PROGRAM FOR INFORMATION.

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Review Exercise

1. What does the acronym UNAMAP stand for?	
2. UNAMAP is available a. to make a profit for NTIS. b. to require the air quality modeler to use U.S. EPA models. c. as a public service. d. to make Mr. Turner famous. e. as a repository for all U.S. EPA models.	1. User's Network for Applied Modeling of Air Pollution
3. The agency responsible for deciding which models are included in UNAMAP is the a. Meteorology and Assessment Division of ESRL. b. Source Receptor Analysis Branch of OAQPS. c. Monitoring and Data Analysis Division of HERL.	2. c. as a public service.
4. The latest UNAMAP version number (as of 1982) is __________.	3. a. Meteorology and Assessment Division of ESRL.
5. What is one problem that may arise for persons desiring to use UNAMAP? a. If they do not use a UNIVAC computer, changes to the model software may be necessary. b. The user may have a machine with tape drives; this package is supplied on disk **only.** c. The user must have a computer with the basic language.	4. four (4)
	5. a. If they do not use a UNIVAC computer, changes to the model software may be necessary.

Lesson 2
PTXXX Models:
PTMAX, PTDIS, and PTMTP

Lesson Goal and Objectives

Goal

To familiarize you with plume distribution, method of plume rise, sigma y and sigma z, data entries, limitations, and use of the PTXXX models, which include PTMAX, PTDIS, and PTMTP.

Objectives

At the end of this lesson, you should be able to:

1. describe the plume distribution of the PTXXX models.
2. recognize the reason a time average of conditions is necessary for a Gaussian distribution.
3. identify the reason Gaussian plume models may not give accurate estimates of pollution.
4. define sigma y and sigma z.
5. name the two methods of entering data for the PTXXX models.
6. state the reason the PTXXX models are used as screening models.

Introduction

PTXXX models
PTMAX PTDIS PTMTP

The first models to be discussed all belong to the series of models known as the PTXXX models. Three model acronyms—PTMAX, PTDIS, and PTMTP—all represent the specific use intended for each model. For example, the PTMAX model letters stand for Point Maximum, meaning the model calculates the maximum ground-level pollutant concentrations for point sources. PTDIS is the Point Distance model that determines the downwind profile of concentrations with distance. PTMTP is the Point-Multi-Point model that can calculate impacts for more than one point source on a field of receptors. The PTXXX models were among the first operational air quality models to be used. They were derived from the techniques in the *Workbook for Atmospheric Dispersion Estimates* (WADE) by D. Bruce Turner (Figure 4-2). This lesson will discuss the model's plume distribution input, limitations, and use and output. While the PTXXX models evolved from a common approach, each of the three variations was intended to produce results in addition to the standard output, maximum ground-level concentrations. This extra information that the user has to specifically ask for is called an option.

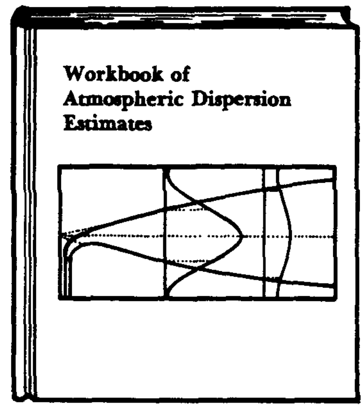


Figure 4-2. WADE.

Plume Characteristics

The models are called Gaussian because the pollutant mass within the plume is assumed to follow a bell-shaped curve, called the normal distribution (Figure 4-3). A normal, or Gaussian, distribution is one in which the maximum concentrations occur in the middle of the plume and taper exponentially to almost zero at the edges, as in Figure 4-4. The edge of the plume is defined by the point where the concentration drops to 10% of the centerline value. For example, if the maximum concentration is 220 $\mu g/m^3$ at centerline, then the edge would occur where the concentration was 22 $\mu g/m^3$. The use of the Gaussian distribution as a basis for plume descriptions is a simplifying assumption.

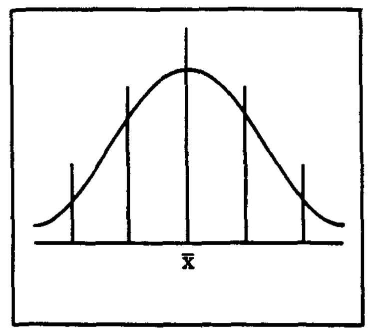


Figure 4-3. Normal distribution.

Boundary Conditions

This one major assumption incorporates a number of other supporting assumptions called boundary conditions. The first supporting assumption is that the atmosphere and source are in steady state. Being steady state means that the atmosphere and source conditions are constant over a period of time. For the PTXXX models, meteorology and emission conditions are assumed to be invariant for a 1-hour period. Therefore, this is not an **instantaneous** picture of conditions. Since, in reality, both the atmosphere and source are variable over periods of time, an average must be taken that uses many instantaneous pictures.

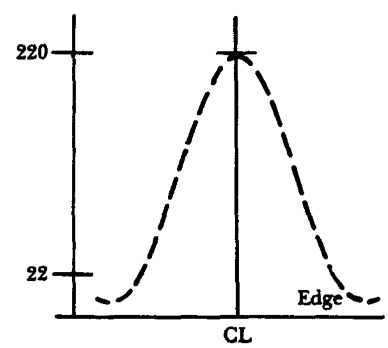


Figure 4-4. Plume distribution.

The second supporting assumption is that no pollutant mass is lost from the plume through chemical reaction or physical deposition on a surface. This is called conservation of mass.

The third supporting assumption is that the plume does not stretch in the downwind direction. This means that the pollutant material through any slice, or cross section, of the plume is the same as any other cross section of the plume; distance from the source does not matter.

Assumptions
1. Steady state
2. No removal
3. No downwind stretching
4. Stable pollutant
5. Average wind

The last supporting assumption is that an average wind speed and direction can be identified for the 1-hour period, and that they are typical of the atmospheric layer that will disperse the plume.

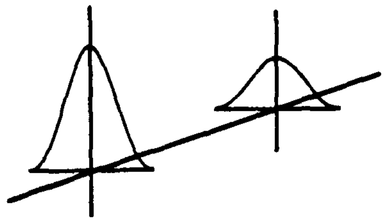


Figure 4-5. Boundary conditions.

Accuracy of Model

Boundary conditions limit the model's ability to fully describe the physical conditions of the source and atmosphere. This means that models using the Gaussian distribution may not estimate pollutant concentrations accurately (Figure 4-5). The assumptions are the reasons that the model results are conservative. That is, the estimates of downwind concentrations are larger than may be observed at a real receptor. Using the PTXXX models, a calculation for a new source will overestimate the source's effect on air quality. Three factors called plume rise, sigma y, and sigma z must be input to estimate pollution concentration.

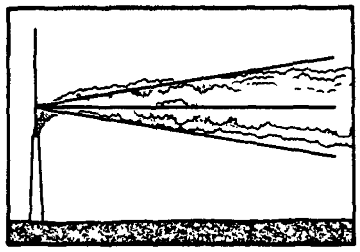
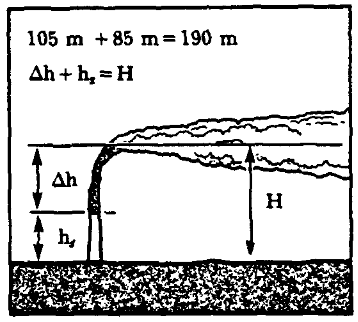


Figure 4-6. Plume rise method.

Plume Rise Method

The distance above the stack that the plume centerline will climb before leveling off is called plume rise (Figure 4-6). Plume rise, Δh, is calculated using formulas developed by G. A. Briggs. The Briggs' formulas for stable or neutral atmospheric conditions use the Pasquill-Gifford (P-G) stability classifications A through D. (A through D are identified for the computer as 1 through 4.) When the atmosphere is stable, P-G classifications E and F (computer identified as 5 and 6) are used in the formulas. The plume rise, Δh, is added to the physical height of the stack, h, resulting in the effective plume rise, H (Example 4-1).



Example 4-1. Plume rise calculation.

H is the calculated centerline of the plume, not the plume edge. The centerline is where the maximum pollution concentration occurs. Our first concern is the plume centerline's relationship to ground level. The relationship allows the calculation of an estimate of maximum ground-level concentrations with distance from a source. Ground-level concentrations are reduced as the plume rises. For example, let the conditions of the atmosphere and the source remain constant and the physical stack height increase from 10 to 20 meters, as in Figure 4-7. The ground-level concentrations may decrease by a calculated factor. Therefore, plume rise, Δh, is an important calculation in the models.

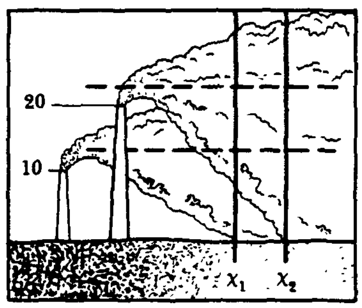


Figure 4-7. χ difference due stack height.

Sigma y and Sigma z

The factors called sigma y and sigma z are the horizontal and vertical dispersion parameters, and their distribution is called binormal (Figure 4-8). In effect, they are the standard deviations of the plume concentration distribution in horizontal and vertical directions. The sigmas are measures of the Gaussian distribution. The edge of the plume, at which the concentration is 10% of the centerline, is 2.15 standard deviations from the center. The values for sigma y and sigma z, found in graphs by Turner, give the rate of dispersion as a function of stability class (A through F) and downwind distance. The values of sigma y and sigma z estimate the width of a plume as it travels downwind. Dispersion rates are also a very important part of calculating pollution concentrations.

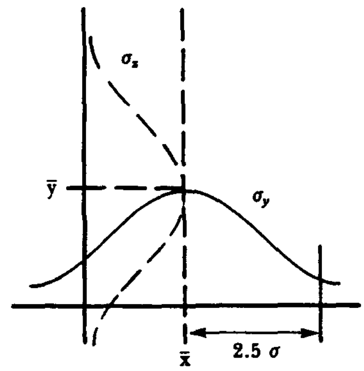


Figure 4-8. Binormal distribution.

Computer Modes

The PTXXX models may be run in two modes: batch (Figure 4-9) and interactive (Figure 4-10). In the batch mode, all inputs to the computer are on IBM cards or card images. These cards are placed in a reader machine and the data is transferred to the computer for processing. In the interactive mode, the computer will ask for input data as they are needed. The user must have a special typewriter keyboard, called a remote terminal, in order to access the models in this mode. The batch mode method is a faster and slightly less expensive method than the interactive mode. However, the interactive mode is usually more convenient. The PTXXX models' inputs are very similar to each other.

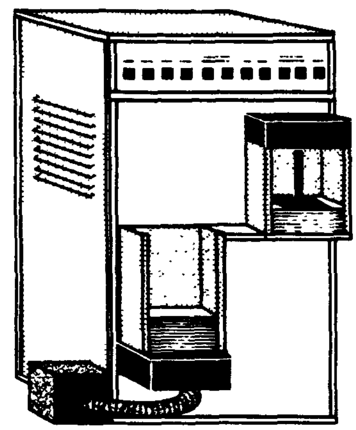


Figure 4-9. Batch mode card reader.

Inputs

As shown in Table 4-1, all PTXXX models require inputs such as source emission strength (Q), stack height (h_s), stack gas temperature (T_s), stack diameter (d), stack gas velocity (v_s), ambient air temperature (T_a), and P-G stability category (1 through 6, A through F). The source strength, Q, given in grams per second, is the amount of pollution leaving the stack per second. The stack height, h_s, given in meters, is the actual height of the stack. The stack gas temperature, T_s, given in Kelvin, is the temperature at which the pollution leaves the stack. The stack gas velocity, v_s, given in meters per second, is the speed at which the pollution leaves the stack. The stack diameter, d, given in meters, is the width of the stack opening. The ambient air temperature, T_a, given in Kelvin, is the outside air temperature. The Pasquill-Gifford atmospheric stability

Figure 4-10. Interactive mode terminal.

categories A through F, which are coded as 1 through 6, are used to calculate values for sigma y and sigma z. The inputs that are not the same for the variations of the PTXXX are shown in Table 4-1 also.

Table 4-1. PTXXX inputs.

Input by user			PTMAX	PTDIS	PTMTP*
Ambient air	T_a	(K)	yes	yes	yes
Wind speed	$\bar{u}$	(m/s)	no	yes	yes
Source emission strength	Q	(g/s)	yes	yes	yes
Mixing height	L	(m)	no	yes	yes
Stack height	h_s	(m)	yes	yes	yes
Stack gas temperature	T_s	(K)	yes	yes	yes
Stability classes	1-6		yes	yes	yes
Stack diameter	d	(m)	yes	yes	yes
Stack velocity	v_s	(m/s)	yes	yes	yes
Receptor locations (x,y coordinates)			no	yes	yes
Isopleth values		(g/m³)	no	yes	no
Averaging times		(s)	no	no	yes

*Considers multiple sources

Limitations

The PTDIS and PTMTP models do require that the average wind speed, $\bar{u}$ in m/s, be entered. However, the PTMAX has predetermined wind speeds within the model for each stability. These wind speeds are considered appropriate for each stability category. The PTDIS and PTMTP models require a mixing height, L, entry (Figure 4-11). The PTMAX model does not consider any situation that involves a limitation to mixing. The PTDIS and PTMTP models require an entry for the number of receptor sites that are to be considered and the distance to each from the source. The PTMAX is designed to calculate the distance to the maximum concentration for each P-G stability category A through F and each of the predetermined wind speeds.

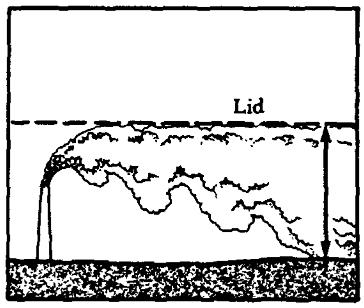


Figure 4-11. Mixing height.

The PTDIS model has an option that will help in drawing concentration isopleths (lines of equal concentrations) on a map, as shown in Figure 4-12. The model asks for the number of isopleths desired in their strength. Also, the model needs to know whether 16-point wind information or 36-point wind information is used. The PTMAX and PTMTP models do not consider isopleths.

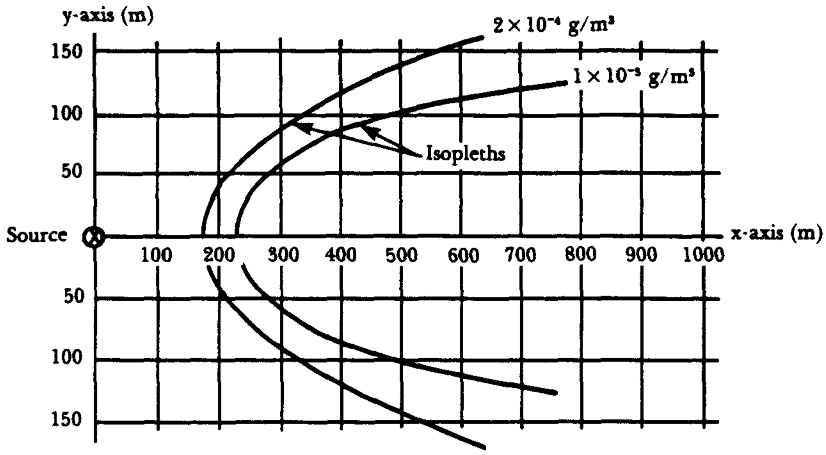


Figure 4-12. Ground-level concentration isopleths.

The PTMTP model will produce a time-averaged concentration for periods longer than 1 hour. The model merely adds the hourly concentrations and divides by the number of concentrations involved in the addition. The PTMAX and PTDIS models consider only hourly averages.

To the novice air quality modeler it may not be apparent that the PTXXX models are simple models. They are used as screening models. This means they will analyze a limited number of sources, meteorological conditions, and receptors, and will yield a conservative estimate of concentration. If more detail about concentrations is needed, the PTXXX models should not be used. As the other models are examined, the simplicity of the PTXXX should become obvious.

Use and Output

Because of their simplicity, the PTXXX models in Figures 4-13 to 4-15 cost less than one dollar to produce. Most applications are inexpensive.

The first example, Figure 4-13, is a run for the PTMAX model. The input on the left side of the page produces the output on the right. Under the output, column one provides all six P-G stabilities; column two gives the predetermined wind speeds for each stability; column three gives maximum concentrations for each stability and maximum concentrations for distances given in column four; column five gives the final plume rise heights.

This output allows the user to identify the *critical* wind speed for each stability. Critical wind speed means the wind speed that allows the highest concentrations at a specific stability to occur.

Figure 4-14 is an example of the PTDIS model run. Note the similarity to the PTMAX interactive mode entries. Also note the differences that have been mentioned. In section one, column one, are the preselected receptor distances; in column two is final plume rise; in column three are the maximum concentrations; in columns four and five are the sigma y and sigma z values at the receptor distances. Output section two gives the information necessary for drawing concentration isopleths. Each value of sigma y given in the half-width column is the distance from the x-axis (mean wind direction) to the isopleth value above. For example, the first isopleth value is 0.1×10^{-2}. The half-width is given at 300 meters as 57 meters. The partially drawn isopleth was shown in Figure 4-12.

```
READY
ptmax
ENTER ALPHANUMERIC TITLE OF UP TO 64 CHARACTERS, OR "END".
?
test of ptmax 10/4/79
ENTER AMBIENT AIR TEMPERATURE (DEG K) OR ZERO TO USE DEFAULT VALUE
OF 293.
?
0
ENTER SELECTED STABILITY CLASS OR ZERO (0) FOR ALL STABILITIES
?
0
ENTER SOURCE STRENGTH (G/SEC)
?
287
ENTER PHYSICAL STACK HEIGHT (M)
?
30
ENTER STACK GAS TEMPERATURE (DEG K)
?
350
ENTER VOLUME FLOW (M**3/SEC) IF KNOWN, OR ZERO (0) IF NOT KNOWN
?
0
ENTER STACK GAS VELOCITY (M/SEC)
?
20
ENTER STACK DIAMETER (M)
?
0.6
```

```
TEST OF PTMAX 10/4/79
ANALYSIS OF CONCENTRATION AS A FUNCTION OF STABILITY AND WIND SPEED.
VERSION 75128, D. B. TURNER.

EMISSION RATE (G/SEC) = 278.00
PHYSICAL STACK HEIGHT (M) = 30.00
STACK GAS TEMP (DEG K) = 350.00
AMBIENT AIR TEMPERATURE (DEG K) = 293.
STACK GAS VELOCITY (M/SEC) = 20.00
STACK DIAMETER (M) = .60
VOLUME FLOW (CU M/SEC) = 5.65
```

Col. no. (1)	(2)	(3)	(4)	(5)
STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HEIGHT (M)
1	0.5	7.7219E-03	0.486	124.6
1	0.8	7.9789E-03	0.397	89.1
1	1.0	8.0089E-03	0.357	77.3
1	1.5	7.7614E-03	0.297	61.5
1	2.0	7.3243E-03	0.264	53.6
1	2.5	6.8569E-03	0.243	48.9
1	3.0	6.4449E-03	0.229	45.8
2	0.5	5.9313E-03	0.858	124.6
2	0.8	6.8110E-03	0.632	89.1
2	1.0	7.0593E-03	0.555	77.3
2	1.5	7.1534E-03	0.445	61.5
2	2.0	6.9109E-03	0.387	53.6
2	2.5	6.5671E-03	0.352	48.9
2	3.0	6.2193E-03	0.329	45.8
2	4.0	5.5448E-03	0.300	41.8
2	5.0	4.9602E-03	0.283	39.5
3	2.0	6.9162E-03	0.593	53.6
3	2.5	6.6545E-03	0.536	48.9
3	3.0	6.3366E-03	0.498	45.8
3	4.0	5.6913E-03	0.452	41.8
3	5.0	5.1156E-03	0.424	39.5
3	7.0	4.2116E-03	0.392	36.8
3	10.0	3.3027E-03	0.368	34.7
3	12.0	2.8817E-03	0.359	33.9
3	15.0	2.4164E-03	0.350	33.2
4	0.5	2.7076E-03	4.218	124.6
4	0.8	3.8535E-03	2.469	89.1
4	1.0	4.3419E-03	1.978	77.3
4	1.5	5.0153E-03	1.387	61.5
4	2.0	5.2362E-03	1.120	53.6
4	2.5	5.2049E-03	0.980	48.9
4	3.0	5.0042E-03	0.912	45.8
4	4.0	4.5535E-03	0.827	41.8
4	5.0	4.1275E-03	0.777	39.5
4	7.0	3.4331E 03	0.719	36.8
4	10.0	2.7143E-03	0.676	34.7
4	12.0	2.3762E-03	0.660	33.9
4	15.0	1.9993E-03	0.643	33.2
4	20.0	1.5790E-03	0.626	32.4
5	2.0	2.8291E-03	2.547	61.0
5	2.5	2.4885E-03	2.403	58.7
5	3.0	2.2350E-03	2.294	57.0
5	4.0	1.8775E-03	2.139	54.6
5	5.0	1.6334E-03	2.031	52.8
6	2.0	2.4535E-03	4.410	55.7
6	2.5	2.1665E-03	4.120	53.9
6	3.0	1.9514E-03	3.906	52.4
6	4.0	1.6456E-03	3.603	50.4
6	5.0	1.4270E-03	3.434	48.9

```
ENTER ALPHANUMERIC TITLE OF UP TO 64 CHARACTERS, OR "END".
?
end
```

Figure 4-13. PTMAX model run.

```
READY
ptdis
DO YOU WANT THE PRECAUTIONARY MESSAGE PRINTED? ENTER YES OR NO
?
YES
   CARE SHOULD BE EXERCISED IN THE INTERPRETATION OF THESE CALCULATED
CONCENTRATIONS. CONCENTRATION ESTIMATES MAY BE EXPECTED TO BE
WITHIN A FACTOR OF THREE FOR: 1) ALL STABILITIES OR DISTANCES
OF TRAVEL OUT TO A FEW HUNDRED METERS. 2) NEUTRAL TO MODERATELY
UNSTABLE CONDITIONS FOR DISTANCES OUT TO A FEW KILOMETERS.
3) UNSTABLE CONDITIONS IN THE LOWER 1000 METERS OF THE ATMOSPHERE
WITH A MARKED INVERSION ABOVE FOR DISTANCES OUT TO TEN KILOMETERS
OR MORE. FOR OTHER CONDITIONS THESE ESTIMATES BECOME LESS RELIABLE
FOR EXTREMES OF STABILITY AND AS TRAVEL DISTANCE INCREASES.

ENTER ALPHANUMERIC TITLE (UP TO 64 CHARACTERS)
?
TEST OF PTDIS 10/4/79
ENTER NUMBER OF DISTANCES FOR WHICH CALCULATIONS ARE TO BE
MADE. MAXIMUM 50
?
5
ENTER DISTANCES (KM) SEPARATED BY COMMAS OR SPACES
?
0.1,0.2,0.3,0.4,0.5
DO YOU WANT THE ISOPLETH OPTION? ENTER YES OR NO
?
YES
ENTER NUMBER OF ISOPLETHS TO BE CONSIDERED, MAXIMUM OF 8
?
3
ENTER ISOPLETH VALUES (G/M**3) SEPARATED BY COMMAS OR SPACES
?
1.0E-03,2.0E-04,1.0E-04
ENTER WIND SEGMENT SIZE (DEG)
?
22.5
ENTER SOURCE STRENGTH
?
287
ENTER EFFECTIVE HEIGHT OF EMISSION (M) IF YOU WISH OR ENTER ZERO
(0) TO HAVE PLUME RISE CALCULATED
?
0
ENTER PHYSICAL STACK HEIGHT (M)
?
30
ENTER STACK GAS TEMPERATURE (DEG K)
?
350
ENTER VOLUME FLOW (M**3/SEC) IF KNOWN, OR ZERO (0) IF NOT KNOWN
?
0
ENTER STACK GAS VELOCITY (M/SEC)
?
20
ENTER STACK DIAMETER (M)
?
0.6
ENTER AMBIENT AIR TEMPERATURE (DEG K), OR ZERO (0) TO USE DEFAULT
VALUE OF 293
?
0
ENTER STABILITY CLASS (1-6)
?
3
ENTER WIND SPEED (M/SEC)
?
4
ENTER MIXING HEIGHT (M)
?
700
```

```
DOWNWIND CONCENTRATIONS FOR SPECIFIC DISTANCES
DBT43 - VERSION 78010.  D. B. TURNER
TEST OF PTDIS 10/4/79
* * * SOURCE CONDITIONS * * *
SOURCE STRENGTH (G/SEC) =   287.0
PHYSICAL STACK HEIGHT (M) =  30.0
STACK GAS TEMPERATURE (DEG K) =  350.0
STACK GAS VELOCITY (M/SEC) =  20.0
STACK DIAMETER (M) =    .6
VOLUME FLOW (M**3/SEC) =     5.7
* * * METEOROLOGICAL CONDITIONS * * *
AMBIENT AIR TEMPERATURE (DEG K) =  293.0
STABILITY CLASS = 3
WIND SPEED (M/SEC) =  4.0
HEIGHT OF MIXING LAYER (M) = 700
FINAL EFFECTIVE HEIGHT OF EMISSION (M) =    41.8
DISTANCE TO FINAL EFFECTIVE HEIGHT (KM) =     .095
```

Col. no. (1)	(2)	(3)	(4)	(5)	(6)
DISTANCE (KM)	HEIGHT (M)	CONCENTRATION (G/CU M)	SIGY (M)	SIGZ (M)	CHI*U/Q (SEC/M**3)
.100	41.8	3.41-008	12.46	7.44	4.75-010
.200	41.8	8.10-004	23.62	14.03	1.13-005
.300	41.8	3.95-003	34.29	20.33	5.50-005
.400	41.8	5.54-003	44.65	26.45	7.72-005
.500	41.8	5.60-003	54.77	32.43	7.80-005

RATIO IS THE HALF-WIDTH OF THE ISOPLETH COMPARED TO THE HALF-WIDTH OF A SECTOR OF 22.5 DEGREES AT THIS DISTANCE.

	ISOPLETH VALUES (GRAMS PER CUBIC METER) .10000-002		.20000-003		.10000-003			
DISTANCE (KM)	HALF-WIDTH (M)	RATIO	HALF-WIDTH (M)	RATIO	HALF-WIDTH (M)	RATIO	HALF-WIDTH (M)	RATIO
.100	0.	.000	0.	.000	0.	.000		
.200	0.	.000	40.	1.006	49.	1.227		
.300	57.	.961	84.	1.412	93.	1.567		
.400	83.	1.045	116.	1.453	127.	1.597		
.500	102.	1.028	142.	1.427	156.	1.568		

```
ENTER "DISTANCE" OR "SOURCE" OR "METEOROLOGY" OR "END"
?
end
READY
```

Figure 4-14. PTDIS model run.

Figure 4-15 is an example of a run for the PTMTP model. Again note input similarities to PTMAX and PTDIS models. Because the PTMTP handles multiple sources, the entries are multiple: one for each stack. This example has four stacks. Section one contains source entries. Section two has 14 receptor distances in x (prec) and y (srec) coordinates. Section three contains meteorological inputs. Section four is part of the hourly concentrations at each receptor 1 through 6, 13, and 14. Receptors 2 through 12 are not shown. Section five is the 3-hour average of the three hourly average concentrations given in section four. The partial concentrations that contribute to the total pollution are given in sections four and five.

```
ENTER ALPHANUMERIC TITLE (UP TO 64 CHARACTERS)
?
TEST OF PTMTP 10/11/79
ENTER NUMBER OF SOURCES TO BE CONSIDERED. MAX 25
4
ENTER SOURCE STRENGTH (G/SEC) FOR EACH STACK
4*287
ENTER PHYSICAL HEIGHT (M) OF EACH STACK
4*30
ENTER GAS TEMPERATURE (DEG K) OF EACH STACK
4*350
IS VOLUME FLOW KNOWN FOR EACH STACK? YES OR NO
?
NO
ENTER GAS VELOCITY (M/SEC) FOR EACH STACK
4*20
ENTER DIAMETER (M) OF EACH STACK
4*0.6
ENTER COORDINATES (KM) OF EACH STACK.  ORDERED PAIRS
1.,0., 1.05,0., 1.10,0., 1.15,0.
ENTER NUMBER OF RECEPTORS TO BE PROCESSED.  MAX 30
14
ENTER COORDINATES (KM) OF EACH RECEPTOR.  ORDERED PAIRS
.8,0., 1.02,0., 1.07,0., 1.12,0., 1.17,0., 1.2,0., 1.3,0.,
1.4,0., 1.5,0., 1.6,0., 1.7,0., 1.8,0., 1.9,0., 2.0,0.
ENTER HEIGHT (M) ABOVE GROUND FOR EACH RECEPTOR
14*0.
ENTER NUMBER OF HOURS TO BE AVERAGED.  MAX 24
3
ENTER WIND DIRECTION (DEG) FOR EACH HOUR
265,270,275
ENTER WIND SPEED (M/SEC) FOR EACH HOUR
4,4,4
ENTER STABILITY CLASS FOR EACH HOUR
3*3
ENTER MIXING HEIGHT (M) FOR EACH HOUR
3*700
ENTER AMBIENT AIR TEMPERATURE (DEG K) FOR EACH HOUR
3*293
DO YOU WANT PARTIAL CONCENTRATIONS PRINTED?  YES OR NO
?
YES
DO YOU WANT HOURLY CONCENTRATIONS PRINTED?  YES OR NO
?
YES
```

Figure 4-15. PTMTP model run (input).

TEST OF PTMTP 10/11/79
MULTIPLE SOURCE MODEL DBT51, VERSION 78010

Section 1

* * * S O U R C E S * * *

NO	Q (G/SEC)	HP (M)	TS (DEG K)	VS (M/SEC)	D (M)	VF (M**3/SEC)	R (KM)	S (KM)
1	287.0	30.0	350.0	20.0	.6	5.7	1.000	.000
2	287.0	30.0	350.0	20.0	.6	5.7	1.050	.000
3	287.0	30.0	350.0	20.0	.6	5.7	1.100	.000
4	287.0	30.0	350.0	20.0	.6	5.7	1.150	.000

Section 2

* * * R E C E P T O R S * * *

NO	RREC (KM)	SREC (KM)	Z (M)
1	.800	.000	.0
2	1.020	.000	.0
3	1.070	.000	.0
4	1.120	.000	.0
5	1.170	.000	.0
6	1.200	.000	.0
7	1.300	.000	.0
8	1.400	.000	.0
9	1.500	.000	.0
10	1.600	.000	.0
11	1.700	.000	.0
12	1.800	.000	.0
13	1.900	.000	.0
14	2.000	.000	.0

Section 3

* * * M E T E O R O L O G Y * * *

NO	THETA (DEG)	U (M/SEC)	KST	HL (M)	T (DEG K)
1	265.0	4.0	3	700.	293.
2	270.0	4.0	3	700.	293.
3	275.0	4.0	3	700.	293.

Section 4

HOUR # 1
* * * R E C E P T O R   N U M B E R * * *

S	HFIN	1	2	3	4	5	6
		PARTIAL CONCENTRATIONS (G/M**3)					
1	42.	.000	.000	4.651-013	1.554-006	1.733-004	6.014-004
2	42.	.000	.000	.000	4.651-013	1.554-006	4.653-005
3	42.	.000	.000	.000	.000	4.651-013	2.405-008
4	42.	.000	.000	.000	.000	.000	8.147-021
		TOTAL CONCENTRATION (G/M**3)					
		.000	.000	4.651-013	1.554-006	1.749-004	6.480-004

HOUR # 1
* * * R E C E P T O R   N U M B E R * * *

S	HFIN	7	8	9	10	11	12
		PARTIAL CONCENTRATIONS (G/M**3)					
1	42.	2.925-003	4.072-003	4.080-003	3.669-003	3.179-003	2.726-003
2	42.	1.772-003	3.695-003	4.164-003	3.898-003	3.424-003	2.945-003
3	42.	6.014-004	2.925-003	4.072-003	4.080-003	3.669-003	3.179-003
4	42.	4.563-005	1.772-003	3.695-003	4.164-003	3.898-003	3.424-003
		TOTAL CONCENTRATION (G/M**3)					
		5.344-003	1.246-002	1.061-002	1.581-002	1.417-002	1.227-002

HOUR # 1
* * * R E C E P T O R   N U M B E R * * *

S	HFIN	13	14
		PARTIAL CONCENTRATIONS (G/M**3)	
1	42.	2.337-003	2.014-003
2	42.	2.523-003	2.168-003
3	42.	2.726-003	2.337-003
4	42.	2.945-003	2.523-003
		TOTAL CONCENTRATION (G/M**3)	
		1.053-002	9.043-003

Section 5

AVERAGE CONCENTRATIONS FOR 3 HOURS.
* * * R E C E P T O R   N U M B E R * * *

S	1	2	3	4	5	6
	PARTIAL CONCENTRATIONS (G/M**3)					
1	.000	.000	5.367-013	1.751-006	1.935-004	6.704-004
2	.000	.000	.000	5.367-013	1.751-006	5.206-005
3	.000	.000	.000	.000	5.367-013	2.737-008
4	.000	.000	.000	.000	.000	9.833-021
	TOTAL CONCENTRATION (G/M**3)					
	.000	.000	5.367-013	1.751-006	1.952-004	7.224-004

* * * R E C E P T O R   N U M B E R * * *

S	7	8	9	10	11	12
	PARTIAL CONCENTRATIONS (G/M**3)					
1	3.263-003	4.557-003	4.582-003	4.135-003	3.595-003	3.091-003
2	1.975-003	4.128-003	4.669-003	4.386-003	3.865-003	3.335-003
3	6.704-004	3.263-003	4.557-003	4.582-003	4.135-003	3.595-003
4	5.206-005	1.975-003	4.128-003	4.669-003	4.386-003	3.865-003
	TOTAL CONCENTRATION (G/M**3)					
	5.960-003	1.392-002	1.794-002	1.777-002	1.598-002	1.389-002

* * * R E C E P T O R   N U M B E R * * *

S	13	14
	PARTIAL CONCENTRATIONS (G/M**3)	
1	2.658-003	2.297-003
2	2.886-003	2.469-003
3	3.091-003	2.658-003
4	3.335-003	2.866-003
	TOTAL CONCENTRATION (G/M**3)	
	1.195-002	1.029-002

ENTER "SOURCES" OR "RECEPTORS" OR "METEOROLOGY" OR "END"
?
END

Figure 4-15. PTMTP model run (output), continued.

Review Exercise

1. The PTXXX models are Gaussian plume models. This means that a. the plume spreads vertically, but not horizontally. b. the maximum concentrations occur in the middle of the plume. c. the models estimate time-averaged concentrations. d. both b and c	
2. Time averages of conditions, such as wind speed, are necessary for a Gaussian distribution because a. conditions are variable with time. b. instantaneous wind readings are not possible. c. instantaneous wind readings are possible but expensive. d. steady-state conditions are not assumed.	1. d. both b and c
3. In Gaussian plume distributions, the edge of the plume is defined as a. the visible edge of the plume. b. the point where concentration drops to 10% of the centerline concentration. c. being determined by each individual plume. d. not being important to concentration estimates.	2. a. conditions are variable with time.
4. One of the supporting assumptions for the Gaussian distribution is steady-state conditions. Being steady state means that a. the atmosphere is sampled instantaneously. b. the atmosphere is always the same no matter how long the time period. c. there aren't any variations in the atmosphere. d. conditions are constant for a given period of time.	3. b. the point where concentration drops to 10% of the centerline concentration.
5. The PTXXX models are conservative in estimating downwind concentrations. This means that a. concentration estimates are larger than actual observations. b. actual observations are always larger than the concentration estimates. c. concentration estimates are the same as actual observations. d. concentration estimates are impossible to make.	4. d. conditions are constant for a given period of time.
	5. a. concentration estimates are larger than actual observations.

6. Plume rise calculations are important for estimating ground-level concentrations because they a. determine the distance of the centerline of the plume above the ground. b. calculate an instantaneous picture of centerline concentrations. c. calculate average concentrations at stack level. d. both a and c	
7. Sigma y and sigma z are also important for estimating ground-level concentrations because they a. determine the lateral and vertical spread of the plume at specific distances downwind. b. determine the concentrations at stack level. c. are the horizontal and vertical dispersion parameters. d. both a and c	6. a. determine the distance of the centerline of the plume above the ground.
8. The PTXXX models may be entered into the computer by two methods. They are a. interactive and modal. b. interactive and batch. c. modal and batch. d. manual and modal.	7. d. both a and c
9. The PTXXX models are called screening models because they a. estimate ground-level concentrations accurately. b. are refined, detailed models. c. make conservative estimates of ground-level concentrations. d. both a and b	8. b. interactive and batch.
10. The PTXXX models calculate plume rise using a. Briggs' urban sigmas. b. Briggs' plume rise formulas. c. Moses and Carson plume rise formulas. d. Turner's *Workbook* values.	9. c. make conservative estimates of ground-level concentrations.
11. The three models of the PTXXX series are a. PTMIN, PTMAX, PTMPP. b. PTPTP, PTMIN, PTDIS. c. PTDIS, PTMAX, PTMTP.	10. b. Briggs' plume rise. formulas.
	11. c. PTDIS, PTMAX, PTMTP.

Lesson 3
PTPLU

Lesson Goal and Objectives

Goal

To familiarize you with the refinements of wind speed corrections, stack-tip downwash, gradual plume rise, and buoyancy-induced dispersion found in the PTPLU model.

Objectives

At the end of this lesson, you should be able to:
1. name the type of plume distribution used in formulating the PTPLU model.
2. list the three technical options that differentiate the PTPLU model from PTXXX models.
3. identify the model's useful range from the source.
4. describe the effect of each of the three technical options on the calculations for ground-level concentrations.
5. choose the highest estimated concentration from an example of PTPLU output.

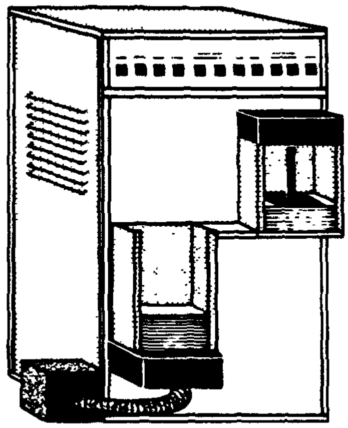


Figure 4-16. Batch mode.

Introduction

The fourth model discussed is PTPLU. It is an improved version of the PTMAX model, discussed in the previous lesson. Three technical options are included in PTPLU. These options are also available in other UNAMAP, Version 4 models more refined than PTPLU. More options indicate that the model is a more detailed screening tool than the PTXXX models. Before discussing the options in PTPLU, let's briefly review the PTMAX model features.

The PTMAX model is a Gaussian (binormally) distributed plume model for single sources. It is steady state and designed for flat, rural areas. The dispersion coefficients are the Pasquill-Gifford sigmas that are applicable only to flat, rural situations. The concentrations are 1-hour averages. PTMAX runs in either batch or interactive mode (Figures 4-16 and 4-17).

Figure 4-17. Interactive mode.

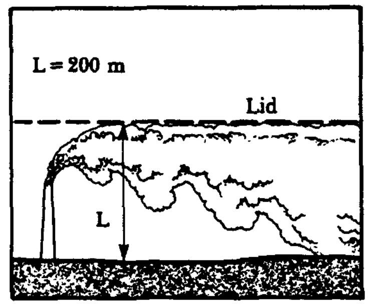
Input Parameters

The inputs required on the PTPLU are the same as PTMAX: source strength, stack height, stack gas temperature, stack gas velocity, stack diameter, and ambient temperature.

The first two physical inputs not required in PTMAX, but required in the PTPLU, are anemometer height and mixing height. The anemometer height is required to extrapolate the winds taken at a lower level (usually 10 meters) to the height of the stack opening (h_s). The wind profile extrapolation uses a power law formula and exponents (p) that are related to the atmospheric stability category to estimate a representative wind speed for plume transport and dispersion. The power law states that wind speed (u) at stack height (z) is a function of wind speed at a lower level (u_o) (Equation 4-1).

(Eq. 4-1) $$u = u_o(z/10)^p$$

The second input, mixing height (L), is used as shown in Example 4-2 to realistically calculate ground-level concentrations when the plume is restricted from dispersing vertically by an elevated inversion (sometimes called a *lid*). This condition results in the plume eventually being well mixed at some distance downwind of the source. This feature differs from PTMAX in that the PTMAX model has no allowance for plume mixing between the ground and an inversion.



Example 4-2. Mixing height under elevated inversion.

Options

The three options of PTPLU are stack-tip downwash, gradual plume rise, and buoyancy-induced dispersion (Figure 4-18). These technical options adjust plume rise and dispersion rates. Weather elements, such as wind speed, are not affected. **Caution:** To ensure regulatory consistency, you should check with the EPA Regional Meteorologist in your region before using any of these options in a permit analysis.

Stack-tip Downwash

The first option, stack-tip downwash, is considered if the exit velocity of the effluent is less than one and one-half times the wind speed estimated at the stack opening. For example, if the wind speed is 14 meters per second, the gas exit velocity at the stack top must be less than 21 meters per second for the effective stack height, H, to be adjusted downward toward the ground. Stack-tip downwash increases ground-level concentrations by lowering the plume's relationship to the ground.

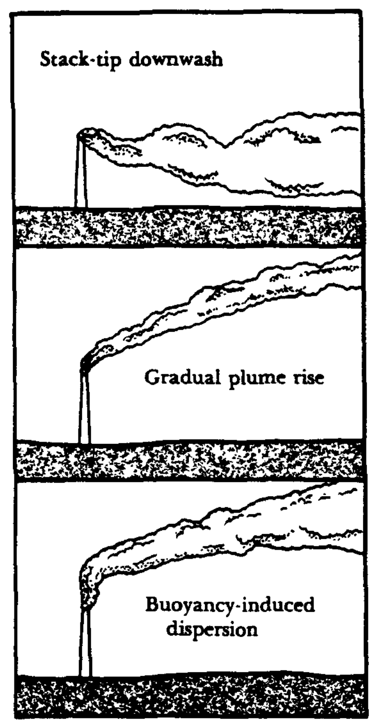


Figure 4-18. PTPLU options.

Gradual Plume Rise

The second option, gradual plume rise, allows the plume to slowly continue rising with distance downwind from the source. The plume will eventually cease rising when the temperature of the plume is the same as the surrounding air. The point where the plume becomes constant with height is called final rise. The PTMAX model uses final rise for all calculations. By using this option, PTPLU will calculate plume rise that is lower than PTMAX. This lower plume rise results in higher ground-level concentrations. At final rise distance and beyond, both models would give the same concentrations.

Buoyancy-induced Dispersion

The third option, buoyancy-induced dispersion, considers that the plume spreads wider and higher than ambient turbulence alone could initially spread it. This initial spreading takes place during the time the plume first comes out of the stack. It is due to the larger amount of entrainment (mixing) of surrounding air into the plume.

Limitations

The limitations of PTPLU are similar to those of PTMAX. Effects that cannot be simulated include building downwash, pollutant removal or chemical reactions, multiple sources, and fumigation. The PTPLU model remains a screening tool, although it is more detailed than its predecessor, PTMAX.

Output

Figure 4-19 gives an example of the batch version of PTPLU. **Section one** is the title. **Section two** gives input parameters. **Section three** gives two calculated values: volumetric flow and buoyancy flux used for plume rise. **Section four** contains output for constant wind speed with height on the left and for extrapolated wind speed with height on the right. For each wind speed and stability combination, the maximum concentration, the distance to maximum, and effective plume height are given. **Section five** prints three caution messages. These correspond to numbers in parentheses in Section four.

When the distance to the maximum concentration is greater than 100 kilometers, the output will print consecutive 9's—for example, 9.999 E+09 grams per second.

Any effective plume height above 200 meters is considered excessive and will be tagged—for example, a plume height of 824.9 (2). The 2 in parentheses keys a cautionary message that care should be used when interpreting the computation. The cost of running PTPLU is the same as that for the PTXXX models, i.e., less than $1.00.

```
PTPLU (VERSION 81036)
AN IMPROVED POINT SOURCE SCREENING MODEL
MODIFIED BY: JOE CATALANO AND FRANK HALE
AEROCOMP, INC. - COSTA MESA, CA        FOR THE
ENVIRONMENTAL OPERATIONS BRANCH, EPA
```

Section 1

```
                                   >>>INPUT PARAMETERS<<<
***TITLE***   PTPLU EXAMPLE RUN - INPUT BY T. PIERCE  12/29/80

***OPTIONS***                     ***METEOROLOGY***                                       ***SOURCE***
IF = 1, USE OPTION                AMBIENT AIR TEMPERATURE =   278.00 (K)                  EMISSION RATE =  1000.00 (G/SEC)
IF = 0, IGNORE OPTION             MIXING HEIGHT           =  1500.00 (M)                  STACK HEIGHT  =   200.00 (M)
IOPT(1) = 0 (GRAD PLUME RISE)     ANEMOMETER HEIGHT       =     7.00 (M)                  EXIT TEMP.    =   450.00 (K)
IOPT(2) = 1 (STACK DOWNWASH)      WIND PROFILE EXPONENTS  = A:0.07, B:0.07, C:0.10        EXIT VELOCITY =    20.00 (M/SEC)
IOPT(3) = 1 (BUOY. INDUCED DISP.)                           D:0.15, E:0.35, F:0.55        STACK DIAM.   =     5.00 (M)

***RECEPTOR HEIGHT*** =      2.00 (M)
```

Section 2

```
                                   >>>CALCULATED PARAMETERS<<<
VOLUMETRIC FLOW =   392.70 (M**3/SEC)      BUOYANCY FLUX PARAMETER =   466.52 (M**4/SEC**3)
```

Section 3

PTPLU EXAMPLE RUN - INPUT BY T. PIERCE 12/29/80

Section 4

STABILITY	****WINDS CONSTANT WITH HEIGHT**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)	****STACK TOP WINDS (EXTRAPOLATED FROM 7.0 METERS)**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
1	0.50	0.0000E+00	0.000	3299.5(2)	0.83	0.0000E+00	0.000	2851.2(2)
1	0.80	0.0000E+00	0.000	2137.2(2)	1.01	0.0000E+00	0.000	1732.0(2)
1	1.00	0.0000E+00	0.000	1749.7(2)	1.26	4.2628E-04	1.893	1425.6(2)
1	1.50	3.9137E-04	1.884	1233.2(2)	1.90	3.4502E-04	1.532	1017.1(2)
1	2.00	3.3549E-04	1.551	974.9(2)	2.53	3.1034E-04	1.280	812.8(2)
1	2.50	3.1038E-04	1.294	819.9(2)	3.16	3.2021E-04	1.130	690.2(2)
1	3.00	3.1728E-04	1.154	716.6(2)	3.79	3.2851E-04	1.050	608.5(2)

STABILITY	****WINDS CONSTANT WITH HEIGHT**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)	****STACK TOP WINDS (EXTRAPOLATED FROM 7.0 METERS)**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
2	0.50	0.0000E+00	0.000	3299.5(2)	0.83	0.0000E+00	0.000	2851.2(2)
2	0.80	0.0000E+00	0.000	2137.2(2)	1.01	0.0000E+00	0.000	1732.0(2)
2	1.00	0.0000E+00	0.000	1749.7(2)	1.28	1.7943E-04	8.001	1425.6(2)
2	1.50	1.5562E-04	7.764	1233.2(2)	1.90	1.3483E-04	6.628	1017.1(2)
2	2.00	1.3268E-04	6.175	974.9(2)	2.53	1.3700E-04	4.634	812.8(2)
2	2.50	1.3650E-04	4.679	819.9(2)	3.16	1.4700E-04	3.957	690.2(2)
2	3.00	1.4472E-04	4.092	716.6(2)	3.79	1.5400E-04	3.535	608.5(2)
2	4.00	1.5571E-04	3.428	587.4(2)	5.06	1.6120E-04	3.006	506.4(2)
2	5.00	1.6101E-04	3.025	509.9(2)	6.32	1.8291E-04	2.684	445.1(2)

STABILITY	****WINDS CONSTANT WITH HEIGHT**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)	****STACK TOP WINDS (EXTRAPOLATED FROM 7.0 METERS)**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
3	2.00	9.2078E-05	14.653	974.9(2)	2.80	9.2853E-05	10.076	754.2(2)
3	2.50	8.8390E-05	11.063	819.9(2)	3.50	1.0128E-04	8.512	643.3(2)
3	3.00	9.5617E-05	9.533	716.6(2)	4.19	1.0710E-04	7.513	568.4(2)
3	4.00	1.0570E-04	7.759	587.4(2)	5.59	1.1349E-04	6.351	477.1(2)
3	5.00	1.1146E-04	6.696	509.9(2)	6.99	1.1555E-04	5.501	421.7(2)
3	7.00	1.1556E-04	5.489	421.4(2)	9.78	1.1345E-04	4.848	358.3(2)
3	10.00	1.1311E-04	4.602	355.0(2)	13.98	1.0538E-04	3.999	310.1(2)
3	12.00	1.0928E-04	4.255	329.1(2)	16.78	1.0068E-04	3.716	289.3(2)
3	15.00	1.0373E-04	3.886	301.6(2)	20.97	9.3312E-05	3.435	268.4(2)

STABILITY	****WINDS CONSTANT WITH HEIGHT**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)	****STACK TOP WINDS (EXTRAPOLATED FROM 7.0 METERS)**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
4	0.50	0.0000E+00	0.000	3299.5(2)	0.83	0.0000E+00	0.000	2074.6(2)
4	0.80	0.0000E+00	0.000	2137.2(2)	1.32	9.9990E+09	999.999(3)	1371.6(2)
4	1.00	0.0000E+00	0.000	1749.7(2)	1.65	9.9990E+09	999.999(3)	1137.3(2)
4	1.50	9.9990E+09	999.999(3)	1233.2(2)	2.48	1.6112E-05	92.689	824.8(2)
4	2.00	9.9990E+09	999.999(3)	974.9(2)	3.31	2.0808E-05	63.598	668.6(2)
4	2.50	1.6235E-05	91.619	819.9(2)	4.13	2.4628E-05	48.580	574.9(2)
4	3.00	1.9170E-05	71.819	716.6(2)	4.96	2.7673E-05	39.601	512.4(2)
4	4.00	2.4067E-05	50.581	587.4(2)	6.61	3.1917E-05	30.008	434.3(2)
4	5.00	2.7801E-05	39.291	509.9(2)	8.27	3.3882E-05	26.220	387.5(2)
4	7.00	3.2541E-05	29.980	421.4(2)	11.57	3.4949E-05	20.591	333.9(2)
4	10.00	3.4767E-05	22.760	355.0(2)	16.53	3.4511E-05	16.401	290.8(2)
4	12.00	3.4927E-05	20.120	329.1(2)	19.84	3.3640E-05	14.770	273.2(2)
4	15.00	3.4718E-05	17.431	301.6(2)	24.80	3.1826E-05	13.201	255.5(2)
4	20.00	3.3589E-05	14.690	272.5(2)	33.07	2.8588E-05	11.691	237.9(2)

STABILITY	****WINDS CONSTANT WITH HEIGHT**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)	****STACK TOP WINDS (EXTRAPOLATED FROM 7.0 METERS)**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
5	2.00	3.8085E-05	88.820(1)	380.6(2)	6.47	2.2232E-05	54.680	321.8(2)
5	2.50	3.5456E-05	80.318(1)	367.1(2)	8.08	1.9687E-05	50.490	313.0(2)
5	3.00	3.2630E-05	74.220	357.3(2)	9.70	1.7787E-05	47.282	308.4(2)
5	4.00	2.8441E-05	65.981	342.9(2)	12.93	1.5021E-05	42.942	296.6(2)
5	5.00	2.5432E-05	60.382	332.7(2)	16.16	1.3611E-05	40.000	287.1(2)

STABILITY	****WINDS CONSTANT WITH HEIGHT**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)	****STACK TOP WINDS (EXTRAPOLATED FROM 7.0 METERS)**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	PLUME HT (M)
6	2.00	9.9990E+09	999.999(3)	349.4(2)	12.64	9.9990E+09	999.999(3)	280.8(2)
6	2.50	9.9990E+09	999.999(3)	338.7(2)	15.80	9.9990E+09	999.999(3)	272.7(2)
6	3.00	9.9990E+09	999.999(3)	330.5(2)	18.96	9.9990E+09	999.999(3)	266.1(2)
6	4.00	9.9990E+09	999.999(3)	318.6(2)	25.28	9.9990E+09	999.999(3)	257.0(2)
6	5.00	9.9990E+09	999.999(3)	310.1(2)	31.60	9.9990E+09	999.999(3)	250.9(2)

(1) THE DISTANCE TO THE POINT OF MAXIMUM CONCENTRATION IS SO GREAT THAT THE SAME STABILITY IS NOT LIKELY TO PERSIST LONG ENOUGH FOR THE PLUME TO TRAVEL THIS FAR.

Section 5

(2) THE PLUME IS CALCULATED TO BE AT A HEIGHT WHERE CARE SHOULD BE USED IN INTERPRETING THE COMPUTATION.

(3) NO COMPUTATION WAS ATTEMPTED FOR THIS HEIGHT AS THE POINT OF MAXIMUM CONCENTRATION IS GREATER THAN 100 KILOMETERS FROM THE SOURCE.

Figure 4-19. Batch run of PTPLU model.

Review Exercise

1. The PTPLU model is a ________ plume type model.	
2. Which of these conditions are represented by the PTPLU model? (More than one answer may apply.) a. complex terrain b. building downwash c. wind speed profile with height d. plume rise e. multiple emission sources	1. Gaussian
3. The three technical options available in the model are ________, ________, and ________.	2. c. wind speed profile with height d. plume rise
4. True or False? The useful distance for calculating downwind concentrations with the PTPLU model is 5 kilometers.	3. • stack-tip downwash • gradual plume rise • buoyancy-induced dispersion
5. In the previous example of PTPLU model output, choose the highest concentration for stability class B(2) for both *winds constant with height* and *stack top winds.*	4. False
6. The PTPLU is called a. a refined model. b. an improved version of the PTMAX model. c. a complex terrain model. d. a photochemical model.	5. Constant winds: 1.61×10^{-4} g/m^3 Extrapolated winds: 1.79×10^{-4} g/m^3
7. The PTPLU model has three technical options available. This means that the model is a a. more detailed screening tool than the PTMAX model. b. carbon copy of the VALLEY model. c. complex terrain model. d. refined model, very similar to CRSTER model.	6. d. an improved version of the PTMAX model.
8. The PTPLU model requires two physical inputs not called for in the PTXXX models. These inputs are a. stack coordinates and distance to property line. b. anemometer height and mixing height. c. anemometer height and stack coordinates. d. thermometer height and anemometer height.	7. a. more detailed screening tool than the PTMAX model.
	8. b. anemometer height and mixing height.

Lesson 4
CRSTER

Lesson Goal and Objectives

Goal

To familiarize you with the CRSTER model—its treatment of stacks, receptors, and terrain features.

Objectives

At the end of this lesson, you should be able to:
1. state the regulatory use of the CRSTER model.
2. describe the method of terrain adjustment in the model.
3. name one limitation of the model.
4. describe the adjustment to the dispersion curves that are used in CRSTER to simulate urban conditions.
5. name the computer program that ensures the meteorological data is in proper format for use in the CRSTER model.
6. give the total number of receptors that can be treated by CRSTER and describe their arrangement.

Introduction

The fifth model discussed in this course is the single-source (CRSTER) model. It is called the single-source model because it simulates up to 19 different point sources, but assumes they are collocated at a single plant site. Thus, the model is well suited for a single industrial facility with several different emission sources. CRSTER is a refined model in the UNAMAP package. It requires a large amount of meteorological input data and has an extensive receptor network. As a result, CRSTER is a larger computer program than the screening models discussed previously, and, like all refined models, it runs in a batch mode only. CRSTER is EPA's **benchmark** model for rural areas. This means that any other model applied to rural areas should use the same dispersion equations and assumptions as those found in CRSTER.

Model Assumptions

CRSTER is based on the binormal Gaussian plume equation (Equation 4-2) and uses Briggs' plume rise algorithm.

(Eq. 4-2) $$\chi(x,y) = \frac{Q}{\pi \sigma_y \sigma_z \bar{u}} \exp\left[-\frac{1}{2}\left(\frac{y}{\sigma_y}\right)^2\right] \exp\left[-\frac{1}{2}\left(\frac{H}{\sigma_z}\right)^2\right]$$

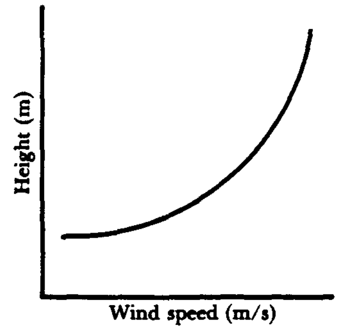
Where:		
	(x,y) = receptor coordinates	(m)
	χ = ground-level concentration	(g/m^3)
	Q = emission rate	(g/s)
	H = effective stack height	(m)
	$\bar{u}$ = mean wind speed	(m/s)
	σ_y, σ_z = dispersion coefficients	(m)

The Gaussian plume model is modified for limited mixing heights and incorporates the Pasquill-Gifford dispersion coefficients. CRSTER is a steady-state model and assumes the source and meteorological conditions are invariant for the basic time period of 1 hour. Pollutant concentrations for longer periods such as 3 hours, 24 hours, and 1 year are produced by averaging together many 1-hour values. The pollutant is assumed to be stable with no chemical reactions or deposition allowed. The wind speed used in the calculations is that at stack top and is estimated from a ground-based (10 meter) wind measurement using the power law wind profile* (Equation 4-3).

(Eq. 4-3) $$u = u_o(h_s/10)^p$$

Follow Example 4-3 to compute the power law formula. Remember wind speed (u) at stack height (h_s) is a function of wind speed at a lower level.

The adjustment for elevated terrain in CRSTER is a new attribute not found in any of the screening models. CRSTER can simulate the effects of "simple terrain"; that is, ground elevations that are no higher than the top of the lowest stack. CRSTER uses the "full height" correction illustrated in Figure 4-20. All receptors are assumed to be ground based. CRSTER takes account of the rise in terrain by decreasing the effective stack height (H) used in the Gaussian plume equation. This is an admittedly simple idea. In reality, terrain can cause significant changes to wind fields and alter the characteristics of turbulence and dispersion.



$$u = u_o(h_s/10)^p$$

Given: Class A stability,
$p = 0.1$
$u_o = 4$ m/s
$h_s = 150$ m

Calculate: $u = 5.2$ m/s

Example 4-3. Power law wind profile.

*Note: z is used in the power law formula for PTPLU = h_s for CRSTER.

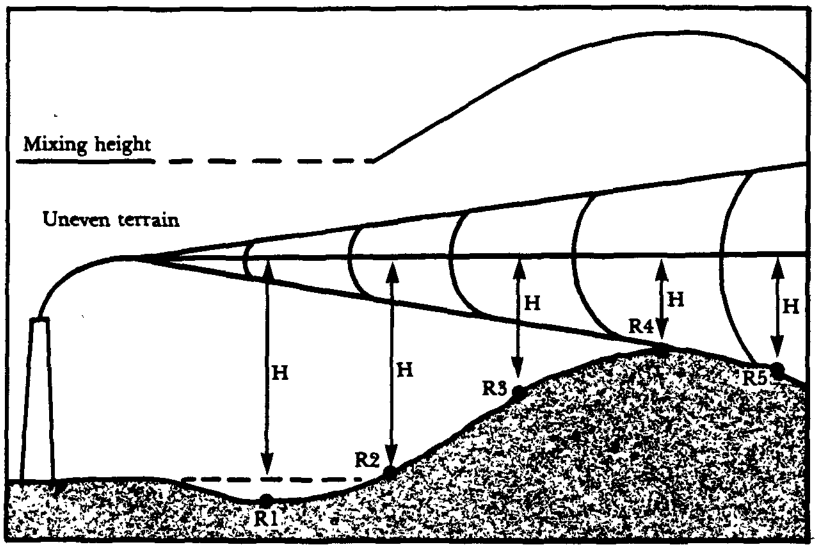


Figure 4-20. Terrain correction in the CRSTER model.

Input Parameters

The CRSTER model requires three basic types of input data: source, receptor site, and meteorological. As mentioned, the model has simulated up to 19 separate point sources which are colocated at a single plant site. The receptor network in CRSTER consists of 180 points arranged on five rings that surround the plant site (Figure 4-21). The receptor points are fixed at 10° azimuth spacing on the rings, but the ring distances from the plant are not fixed and must be specified by the user. The PTPLU screening model is often used to select rings corresponding to the downwind distances where maximum concentrations are expected to occur.

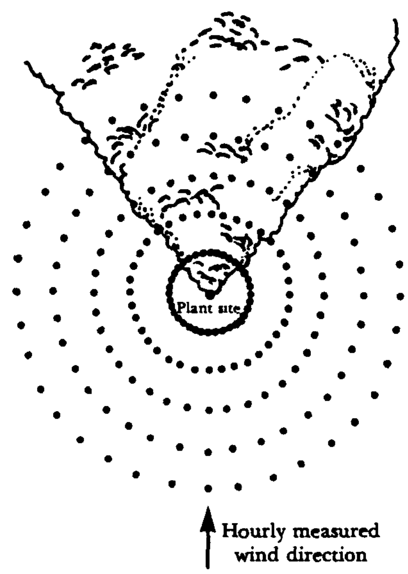


Figure 4-21. Receptor rings and time-averaged plume for Class B conditions using the CRSTER model.

Meteorological data used in the CRSTER model are actual hourly observations from a National Weather Service station for periods ranging from one to five years. These data must first be prepared by the EPA Meteorological Preprocessor, a separate computer program. As shown in Figure 4-22, the preprocessor is driven by a tape of hourly surface meteorological data (wind speed, wind direction, temperature, cloud cover, and ceiling height) and card images of twice-daily mixing heights. The program calculates hourly values of stability class using Turner's method, interpolates mixing heights to hourly values, randomizes the wind direction to 1° increments, reformats other data, and writes all of the parameters out on a magnetic tape. This output is called a Preprocessed Meteorological Data Tape and is read directly by CRSTER and most other EPA refined models. When calm periods are sensed by the preprocessor, the program uses the wind direction from the most recent non-calm hour.

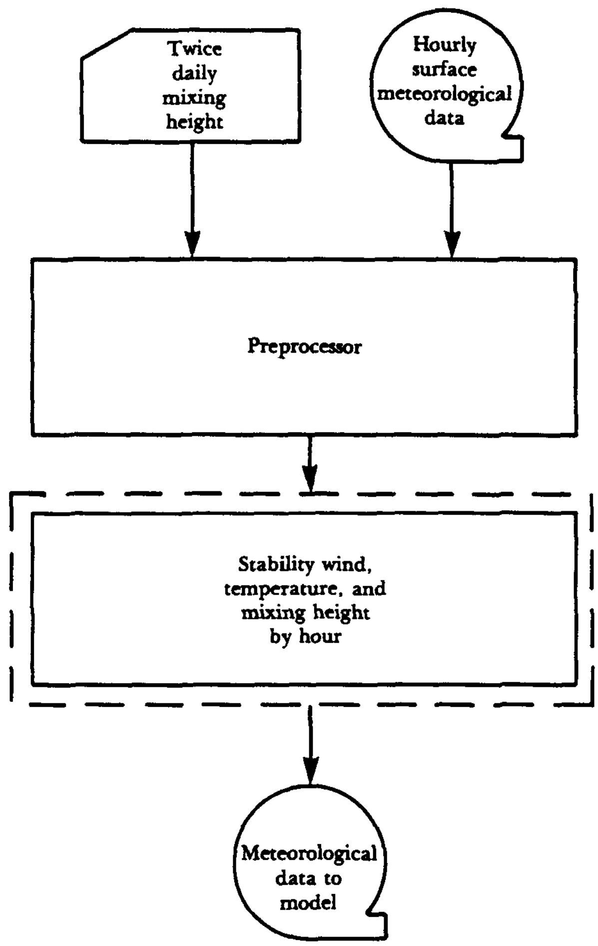


Figure 4-22. Schematic of meteorological data preprocessor.

The tape contains two sets of hourly mixing heights, one for a rural environment and one for an urban environment. Although designed principally for rural areas, CRSTER does have an urban option. When activated, the urban mode uses different mixing height values and modifies the selection of stability class. The principal difference between dispersion in rural and urban environments concerns the occurrence of ground-based temperature inversions in rural areas on calm, clear nights. Pasquill-Gifford stability Classes E and F are associated with these stable conditions. In urban areas, the heat island effect and numerous roughness elements (e.g., tall buildings) increase turbulence and preclude the occurrence of Class E and F conditions. Thus, CRSTER modifies the stability data for a given hour by converting any Class E or F condition to Class D (neutral condition).

Limitations

CRSTER is a refined air quality model with several limitations. Since it is based on the 1-hour steady-state assumption, it is less valid when emissions or meteorological conditions are changing rapidly. It is incapable of treating complex terrain where the ground elevation is higher than stack top, nor can it treat building downwash, pollutant deposition, or chemical transformation.

Output

The CRSTER model provides several different types of output information. Summary tables of highest and second-highest concentrations are generated for averaging times of 1 hour, 3 hours, 24 hours, and 1 year. Additional time periods can be specified. In addition, an output magnetic tape can be written (optional) that archives the full record of dispersion calculations made in the model run. Figure 4-23 is an example of a summary table run by CRSTER, in this case the set of second-highest 3-hour SO_2 concentrations at all 180 receptors. The highest, second-highest SO_2 concentration is highlighted at the top of the page: 6.91×10^{-4} g/m^3 or 691 μg/m^3. Concentrations for each receptor are given in scientific notation and arranged in columns for each ring distance. The numbers in parentheses give the julian day of the year on which the concentration occurred and the time period within that day. For example, (33,4) means julian day 33 (February 2) and the fourth 3-hour period within that day (0900 to 1200 local standard time). CRSTER costs in the range of $50 per year of meteorological data processed.

PLANT NAME: EXAMPLE RUN　　POLLUTANT: SO2　　EMISSION UNITS: GM/SEC　　AIR QUALITY UNITS: GM/M**3

YEARLY SECOND MAXIMUM　　3-HOUR CONC= 6.9140-04　DIRECTION= 10　DISTANCE= 3.8 KM　DAY=130　　TIME PERIOD= 4

SECOND HIGHEST　3-HOUR CONCENTRATION AT EACH RECEPTOR

RANGE / DIR	.9 KM	1.5 KM	2.0 KM	3.8 KM	6.2 KM
1	2.8072-05 (126, 4)	1.3951-04 (125, 5)	1.7750-04 (125, 6)	2.3333-04 (125, 6)	2.4295-04 (143, 6)
2	4.6599-05 (126, 4)	3.6842-04 (125, 4)	5.4116-04 (125, 4)	5.2149-04 (126, 5)	2.9218-04 (126, 5)
3	1.1004-04 (126, 5)	5.3769-04 (125, 4)	6.8883-04 (125, 4)	6.0893-04 (126, 5)	2.7464-04 (126, 5)
4	4.7235-05 (126, 5)	6.8648-04 (142, 5)	5.4122-04 (126, 5)	6.4453-04 (145, 5)	2.7935-04 (126, 6)
5	4.6511-05 (145, 5)	6.4900-04 (145, 5)	5.2231-04 (145, 5)	2.5443-04 (144, 6)	2.5587-04 (144, 6)
6	5.9782-05 (143, 4)	4.9982-04 (142, 5)	3.9222-04 (142, 5)	2.7395-04 (147, 4)	2.0591-04 (133, 5)
7	4.8120-05 (143, 4)	3.0616-04 (140, 5)	4.2424-04 (140, 5)	5.3201-04 (130, 5)	5.9986-04 (134, 6)
8	1.0025-05 (142, 5)	6.7964-05 (140, 4)	1.3242-04 (131, 4)	4.0493-04 (134, 5)	3.0023-04 (130, 3)
9	2.3717-06 (131, 4)	8.2532-05 (131, 4)	1.9277-04 (131, 4)	4.3759-04 (140, 5)	3.0834-04 (145, 7)
10	5.6159-06 (130, 4)	1.3923-04 (131, 5)	4.2902-04 (131, 5)	6.9140-04 (130, 4)	5.4265-04 (141, 1)
11	6.1385-06 (131, 5)	2.6089-04 (148, 5)	5.0318-04 (130, 4)	3.3638-04 (148, 5)	2.7182-04 (145, 6)
12	9.9347-06 (142, 5)	1.7920-04 (148, 4)	2.2185-04 (148, 5)	3.2241-04 (148, 4)	2.5399-04 (130, 3)
13	6.9326-05 (142, 5)	1.1837-04 (142, 5)	1.2657-04 (148, 4)	3.1008-04 (148, 4)	2.2799-04 (142, 6)
14	2.5316-04 (142, 5)	5.1002-04 (148, 5)	4.4377-04 (142, 4)	2.4907-04 (142, 4)	2.4299-04 (148, 5)
15	4.6508-04 (142, 5)	5.7291-04 (142, 4)	4.4377-04 (142, 4)	3.9034-04 (148, 4)	2.7078-04 (148, 4)
16	3.7640-04 (142, 4)	2.6479-04 (142, 4)	1.9390-04 (142, 4)	1.2778-04 (148, 4)	7.9046-05 (148, 4)
17	8.6169-05 (142, 4)	5.6946-05 (142, 4)	3.7019-05 (142, 4)	5.1005-05 (145, 8)	3.8566-05 (142, 5)
18	1.0033-05 (142, 4)	1.3753-05 (141, 4)	1.2083-05 (141, 4)	2.3316-04 (141, 6)	2.7075-04 (146, 1)
19	3.2493-06 (141, 5)	5.5262-05 (141, 4)	3.3141-04 (141, 4)	2.8660-04 (146, 1)	1.9585-04 (141, 4)
20	5.8065-06 (141, 5)	2.5266-04 (141, 4)	6.0063-04 (141, 4)	4.9865-04 (141, 4)	3.6880-04 (141, 4)
21	1.0076-05 (143, 5)	3.4060-04 (141, 4)	4.5974-04 (141, 4)	3.5139-04 (141, 4)	2.7620-04 (141, 5)
22	7.7991-05 (143, 5)	3.5513-04 (141, 5)	3.7973-04 (141, 4)	3.6178-04 (141, 4)	2.0773-04 (141, 3)
23	3.0518-04 (143, 5)	1.9727-04 (143, 5)	1.1515-04 (143, 5)	1.4925-04 (146, 5)	1.0913-04 (141, 3)
24	2.1249-04 (146, 5)	3.1406-04 (142, 4)	2.4339-04 (142, 4)	2.1713-04 (146, 6)	1.4661-04 (142, 3)
25	7.9995-05 (142, 4)	3.6234-04 (146, 4)	3.5226-04 (146, 5)	2.7275-04 (146, 5)	1.3181-04 (146, 5)
26	4.3966-05 (142, 4)	3.5269-04 (146, 4)	5.3304-04 (146, 4)	5.2809-04 (146, 4)	3.3562-04 (146, 4)
27	2.2064-05 (146, 5)	1.7181-04 (146, 4)	2.4401-04 (146, 4)	2.0568-04 (146, 4)	1.4742-04 (132, 5)
28	4.3048-06 (146, 4)	2.8258-05 (146, 5)	4.0180-05 (132, 5)	1.6355-04 (146, 6)	1.6761-04 (142, 6)
29	7.1851-07 (143, 5)	9.4412-06 (132, 3)	3.1217-05 (146, 6)	1.7950-04 (132, 6)	2.0354-04 (146, 6)
30	3.0534-06 (132, 3)	2.2875-05 (132, 3)	6.4450-05 (125, 4)	2.6785-04 (132, 6)	2.5798-04 (132, 3)
31	1.1108-05 (132, 3)	1.4195-05 (132, 3)	7.6670-05 (132, 3)	1.9751-04 (132, 6)	1.9664-04 (132, 5)
32	3.2464-05 (125, 5)	2.1455-05 (125, 5)	3.5240-05 (143, 6)	1.5626-04 (132, 5)	3.1283-04 (132, 4)
33	1.9298-04 (125, 5)	2.1565-04 (125, 5)	2.0722-04 (125, 5)	2.2094-04 (125, 6)	2.5749-04 (143, 6)
34	1.8818-04 (125, 4)	1.0298-04 (125, 4)	2.2673-04 (142, 5)	3.0002-04 (142, 5)	2.9995-04 (125, 6)
35	3.3069-05 (125, 4)	8.8411-05 (143, 5)	1.8771-04 (143, 5)	2.3386-04 (143, 5)	1.3813-04 (143, 5)
36	7.1844-06 (143, 5)	1.0722-04 (143, 5)	2.2431-04 (143, 5)	2.7178-04 (125, 6)	2.0660-04 (126, 6)

Figure 4-23. Sample CRSTER output.

Review Exercise

1. True or False? The CRSTER is only a screening model.

2. The CRSTER model is called a(n) ________ model by U.S. EPA for rural areas.
   a. benchmark
   b. numerical
   c. complex terrain
   d. industrial source
   e. useless

1. False

3. One limitation of the model is that it will **not**:
   a. handle more than one collocated stack.
   b. treat urban situations.
   c. treat inert pollutants like SO_2.
   d. treat building downwash.
   e. calculate 3-hour averages.

2. a. benchmark

3. d. treat building downwash.

4. The CRSTER model adjusts the P-G dispersion curves for the urban situation by a. using Draxler's dispersion coefficients. b. using Briggs' urban dispersion coefficients. c. using Tennessee Valley Authority dispersion coefficients. d. using the P-G neutral category Class D for nighttime. e. using Brookhaven National Laboratory dispersion curves.	
5. True or False? The CRSTER model uses the Meteorological Preprocessor program to properly prepare the meteorological data.	4. d. using the P-G neutral category Class D for nighttime.
6. The CRSTER Preprocessor program checks the meteorological data for calm winds. When a calm is found in the data, the wind direction used in place of the calm is a. randomly selected. b. substituted by the user. c. taken from the most recent non-calm hour. d. always north. e. left blank.	5. True
7. In Figure 4-23 of CRSTER model output, the highest, second-highest 3-hour SO_2 concentration is __________ and its distance from the source is __________.	6. c. taken from the most recent non-calm hour.
8. The CRSTER model is termed a. the complex terrain model. b. the Briggs' urban model. c. the single-source model. d. the multisource model.	7. 691 $\mu g/m^3$, 3.8 km
	8. c. the single-source model.

9. The CRSTER model will handle up to 19 different sized stacks. The model a. discards all but the largest stack. b. collocates the separate stacks at one plant site. c. increases all stack heights to the height of the tallest stack. d. arithmetically averages all stack heights into one "average" stack.	
10. The CRSTER model will handle uneven terrain. In the event of terrain no higher than stack top, the plume is adjusted by a. passing plume centerline above all terrain heights. b. increasing stack gas temperature. c. decreasing the effective stack height. d. decreasing wind speed.	9. b. collocates the separate stacks at one plant site.
11. How many receptor rings and how many receptors are available in the CRSTER model? a. 5 receptor rings and 180 receptors b. 10 receptor rings and 360 receptors c. 8 receptor rings and 240 receptors d. 3 receptor rings and 180 receptors	10. c. decreasing the effective stack height.
	11. a. 5 receptor rings and 180 receptors

Lesson 5
RAM

Lesson Goal and Objectives

Goal

To familiarize you with the RAM model and the options that make it useful.

Objectives

Upon completing this lesson, you should be able to:

1. state the plume distribution of the RAM model.
2. describe the terrain correction in RAM.
3. state the current recommended regulatory use of the RAM model.
4. identify the dispersion curves that RAM uses to simulate dispersion in urban areas.
5. identify the number of stacks that can be analyzed by RAM.
6. describe the method used by RAM to calculate the wind speed at the stack top.

Introduction

The sixth model we will discuss is the RAM model. It is also called the urban multisource model. It was originally designed for both rural and urban applications. Now, however, for regulatory applications, it is recommended for urban situations only. A newer model, called MPTER, will be used to treat rural multisource situations and will be discussed in the next lesson.

Plume Characteristics

The RAM urban model is a Gaussian plume model. The model assumes that the source and meteorological conditions are steady state. The basic time period for calculations is one hour. It will estimate concentrations for averaging times from an hour to a day. The RAM model has a unique feature among those on EPA's UNAMAP package—it is based on dispersion coefficients different from those of Pasquill-Gifford. The RAM dispersion curves, shown in Figure 4-24, were derived by Briggs from tracer experiments conducted in St. Louis by McElroy and Pooler. These are dispersion curves representative of an urban area. Figure 4-24 compares the RAM urban curves to the rural curves of Pasquill-Gifford. It can be seen that, in general, the urban curves represent a greater rate of dispersion caused by the increased turbulence found in urban areas. The RAM model uses Briggs' equations for plume rise. There is no terrain correction in RAM; the surrounding area is assumed to be perfectly flat.

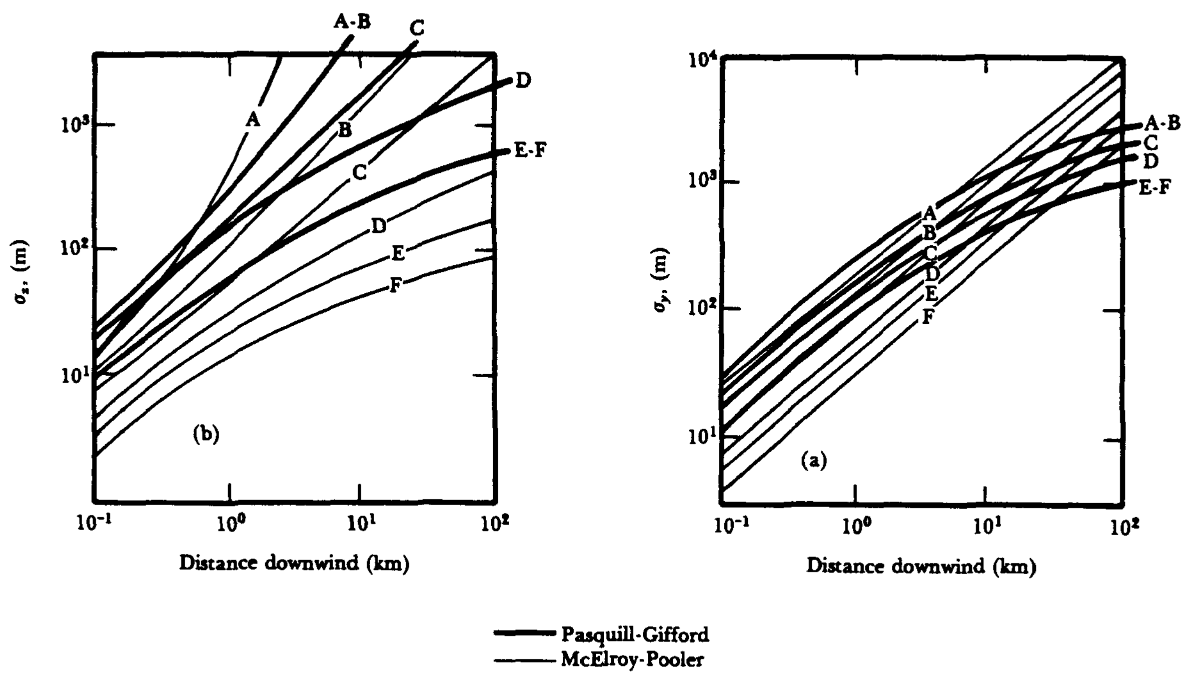


Figure 4-24. RAM dispersion curves.

Input Parameters

As input, the model requires emission information and hourly meteorological data. The same preprocessed meteorological data tape described for CRSTER is used as input to the RAM model. Meteorological information includes hourly values of wind direction and speed, temperature, stability class, and mixing height. Emission information consists of emission rate, physical stack height, stack diameter, stack-gas exit velocity, stack-gas temperature, and stack coordinates. The information required is the same as for other models already discussed, except for the stack coordinates. RAM is a true multiple source model and the coordinates are necessary to calculate the geometry between arbitrary source and receptor locations. The model also calculates a representative wind speed at stack height using the power law formula described in the previous lesson.

The model will allow the user to input a total of 250 stacks—known as point sources—and 100 area sources. Each stack may be of a different height and a total of three area source release heights may be selected. This selection of release heights allows the model to represent several different types of area sources for an urban area.

Limitations

The model does not treat any aspects of terrain, chemical transformations, fumigation, building downwash, or multiple pollutants.

Options

As in the PTPLU model, the effects of stack-tip downwash, gradual plume rise, and buoyancy-induced dispersion can be selected.

Use and Output

RAM is the recommended model for urban areas. The RAM model is recommended for refined analyses only. The user should exercise caution in running the RAM model. Because of internal program calculations, the number of point sources, area sources, receptors, and number of days of analysis should be kept at an absolute minimum. The model, depending on the specific application, can be very expensive to run. Typically, costs will range from 0.10 to 0.20 of one cent per source-receptor-day. A typical modeling run might involve 100 sources, 180 receptors, and 365 days (one year) of meteorology for a total cost of over $6,000.

Figures 4-25 and 4-26 are examples of RAM runs involving typical site situations. Note that, unlike the CRSTER model, RAM output does not use scientific notation for concentration values.

RUN BY: ED KRENSHAW, AIR & HAZARDOUS MATER. DIV., REGION XV,EPA(1 JAN 78)
EMISSIONS: TEST CITY, 1973
SFC MET. DATA: TEST CITY 1973 ; UPPER AIR: TEST CITY 1973

INPUT MET DATA 73/ 1

HOUR	THETA (DEG)	SPEED (M/S)	MIXING HEIGHT(M)	TEMP (DEG-K)	STABILITY CLASS
1	33.00	6.17	429.11	269.82	4
2	23.00	4.63	401.70	271.48	4

RESULTANT MET CONDITIONS

WIND DIRECTION= 28.71 — RESULTANT WIND SPEED= 5.38
AVERAGE WIND SPEED= 5.40 — AVERAGE TEMP= 270.65
WIND PERSISTENCE= .996 — MODAL STABILITY= 4

SIGNIFICANT POINT RECEPTORS

RECEPTOR #	EAST	NORTH	PREDICTED MAX CONC. (MICROGRAMS/M**3)	MAX. DIST (KM)	EFF. HT (M)	U(PHY HT) (M/SEC)
3 P 7	564.43	4407.01	39.39	.902	156.385	8.026
4 P 7	564.16	4406.52		1.804	156.385	8.026
5 P 5	579.45	4403.16	839.47	.166	32.007	6.281
6 P 5	579.40	4403.07		.331	32.007	6.281
7 P 8	577.38	4401.21	448.58	.249	47.506	6.890
8 P 8	577.30	4401.08		.499	47.506	6.890
9 P 9	576.67	4400.55	619.39	.276	52.296	4.753
10 P 9	576.59	4400.40		.551	52.296	4.753
11 P 11	582.94	4400.80	427.63	.187	35.952	6.263
12 P 11	582.89	4400.70		.374	35.952	6.263

SIGNIFICANT AREA SOURCE RECEPTORS

RECEPTOR #	EAST	NORTH
13 A 4	578.42	4399.94
14 A 3	576.4	4399.95
15 A 5	578.4	4401.96
16 A 9	578.43	4405.95
17 A 2	574.43	4399.96
18 A 10	580.41	4405.92
19 A 8	574.43	4405.96
20 A 7	570.87	4403.94
21 A 13	582.41	4403.92
22 A 12	580.41	4403.92

Figure 4-25. RAM model.

RUN BY: ED KRENSHAW, AIR & HAZARDOUS MATER. DIV., REGION XV,EPA(1 JAN 78)
EMISSIONS: TEST CITY, 1973
SFC MET. DATA: TEST CITY 1973 ; UPPER AIR: TEST CITY 1973

SUMMARY CONCENTRATION TABLE(MICROGRAMS/M**3) 73/ 1 : HOUR 1

HOUR	THETA (DEG)	SPEED (M/S)	MIXING HEIGHT(M)	TEMP (K)	STABILITY CLASS
1	33.00	6.17	429.11	269.62	4

AREA HTS: 11., 14., 19.; SEPARATION HTS: 12., 16.

RECEPTOR NO.	EAST	NORTH	TOTAL FROM SIGNIF POINT SOURCES	TOTAL FROM ALL POINT SOURCES	TOTAL FROM SIGNIF AREA SOURCES	TOTAL FROM ALL AREA SOURCES	TOTAL FROM ALL SOURCES	CONCENTRATION RANK
1 I 0	566.00	4405.00	.0000	.0000	.0000	.0000	.0000	41
2 I 0	564.00	4401.50	.0000	.0000	.0000	.0000	.0000	40
3 P 7	564.43	4407.01	35.7987	35.7987	.0000	.0000	35.7987	11
4 P 7	564.16	4406.52	18.2026	18.2026	.0000	.0000	18.2026	15
5 P 5	579.45	4403.16	723.7571	723.7571	1.4215	1.4667	725.2238	1
6 P 5	579.40	4403.07	368.0487	368.0487	1.4465	1.4929	369.5415	5
7 P 8	577.38	4401.21	431.7621	432.2024	2.7281	2.7281	434.9305	3
8 P 8	577.30	4401.08	204.7343	205.1913	2.8280	2.8280	208.0193	7
9 P 9	576.67	4400.55	710.0658	712.6823	2.9602	2.9602	715.6425	2
10 P 9	576.59	4400.40	291.1613	293.7612	3.0427	3.0427	296.8038	6
11 P 11	582.94	4400.80	433.3493	433.3493	.0000	.0483	433.3975	4
12 P 11	582.89	4400.70	194.8263	194.8263	.0000	.0445	194.8708	8
13 A 4	578.42	4399.94	.0837	.0837	3.2543	3.4000	3.4837	24
14 A 3	576.43	4399.95	49.8623	51.6786	3.0868	3.0888	54.7674	9
15 A 5	578.43	4401.96	7.9795	7.9803	1.7745	1.8009	9.7811	21
16 A 9	578.43	4405.95	.0000	.7536	1.1665	1.1665	1.9200	25
17 A 2	574.43	4399.96	.0000	13.8389	1.6338	1.6338	15.4727	17
18 A 10	560.41	4405.92	.0000	.0000	.8464	.8464	.8464	29
19 A 6	574.43	4405.96	.0000	.5625	1.0529	1.0529	1.6154	26
20 A 7	570.87	4403.94	.0000	.0000	.4950	.5121	.5121	33
21 A 13	582.41	4403.92	.0000	.0000	.5493	.6120	.6120	31
22 A 12	580.41	4403.92	.0000	.0000	.5444	.6414	.6414	30
23 H 0	572.00	4400.67	.0000	26.2047	.1834	.3421	26.5468	13
24 H 0	574.00	4400.67	.0000	8.6046	1.2702	1.2702	9.8749	20
25 H 0	580.00	4400.67	.0000	.0000	.2272	.3489	.3489	37
26 H 0	571.00	4402.60	.0000	.0214	.3706	.4890	.5104	34
27 H 0	573.00	4402.60	.0000	19.4521	.2353	.3536	19.8057	14
28 H 0	575.00	4402.60	.0000	9.4123	.1610	.1610	9.5734	22
29 H 0	577.00	4402.60	.0000	29.5180	.3822	.3822	29.9002	12
30 H 0	572.00	4404.33	.0000	.0028	.5696	.5696	.5724	32
31 H 0	574.00	4404.33	.0000	7.2180	.2753	.2753	7.4933	23
32 H 0	576.00	4404.33	.0000	10.9682	.1248	.1248	11.0931	19
33 H 0	578.00	4404.33	.0000	45.5482	.4121	.4121	45.9603	10
34 H 0	571.00	4406.06	.0000	.8200	.3788	.3788	1.1988	27
35 H 0	573.00	4406.06	.0000	.0001	.4319	.4319	.4320	36
36 H 0	577.00	4406.06	.0000	12.9563	.0959	.0959	13.0522	18
37 H 0	572.00	4407.79	.0000	.0000	.1342	.1342	.1342	39
38 H 0	574.00	4407.79	.0000	.0000	.4364	.4364	.4364	35
39 H 0	576.00	4407.79	.0000	.9420	.0000	.0000	.9420	28
40 H 0	578.00	4407.79	.0000	15.2102	.4971	.4971	15.7073	16
41 H 0	580.00	4407.79	.0000	.0000	.2645	.2645	.2645	38

Figure 4-26. RAM model.

Review Exercise

1. The RAM model is a ________ plume model.	
2. True or False? The RAM model can adjust for simple terrain.	1. Gaussian
3. The RAM model is currently recommended for ________ areas only.	2. False
4. The RAM model uses a. Briggs' recommended urban dispersion curves. b. surface wind to represent stack-top wind. c. the preprocessor program to check source data. d. Holland's plume rise methods. e. the method of collocated stacks for point sources.	3. urban
5. True or False? The RAM model uses a linear formula of the form Y = a + bx to adjust the wind speed to stack height.	4. a. Briggs' recommended urban dispersion curves.
6. The RAM model will treat a. building downwash. b. fumigation. c. complex terrain. d. volume sources. e. stack-tip downwash.	5. False
7. True or False? The RAM model is termed a multisource model.	6. e. stack-tip downwash.
8. The RAM model requires (x,y) coordinates for each stack to properly account for the source-receptor geometry.	7. True
9. RAM can handle up to ________ point sources.	8. True
	9. 250

Lesson 6
MPTER

Lesson Goal and Objectives

Goal

To familiarize you with MPTER and its method of treating terrain.

Objectives

Upon completing this lesson, you should be able to:

1. identify MPTER's plume characteristics.
2. list the three technical options available in MPTER.
3. describe MPTER's terrain adjustment method.
4. identify the limitations of MPTER.
5. describe the MPTER method of adjusting wind speed.
6. describe the MPTER method of plume rise.

Introduction

The seventh model to be discussed is the MPTER model. MPTER stands for Multiple Point Source Terrain, and this model is EPA's basic multiple point source model for rural areas. The model is very similar to the RAM model discussed in the previous lesson, except that the MPTER model treats point sources in uneven, rural terrain, whereas the RAM model is designed for urban areas with flat terrain.

Plume Characteristics

The MPTER model is a Gaussian plume model. Consequently, the model assumes that source and meteorological conditions are steady state. The basic time period for calculations is one hour. It will estimate concentrations for averaging times from one hour to one year. The dispersion coefficients are the Pasquill-Gifford rural values found in Turner's *Workbook of Atmospheric Dispersion Estimates* and illustrated in Figure 4-27.

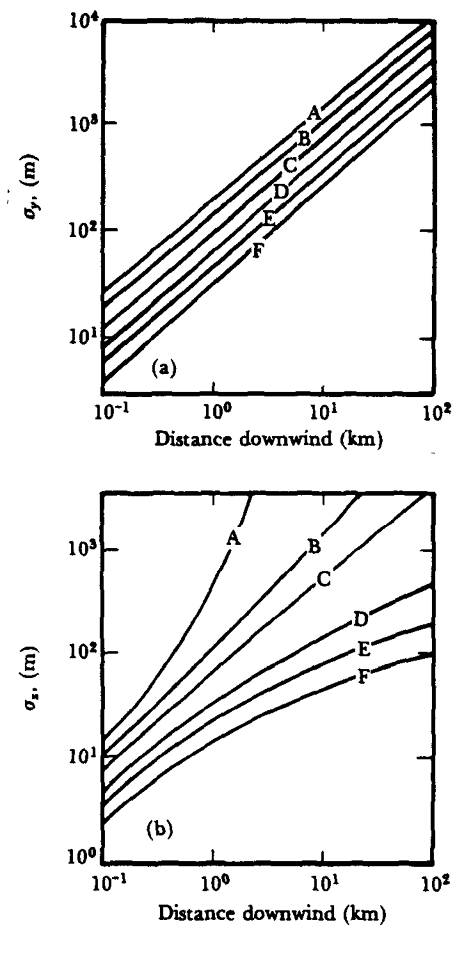


Figure 4-27. MPTER dispersion coefficient values.

Input Parameters

The MPTER model calculates effective plume rise by Briggs' method. As shown in Figure 4-28, this model offers three plume and dispersion options. These options are stack-tip downwash, gradual plume rise, and buoyancy-induced dispersion. Buoyancy-induced dispersion is a concept proposed by Pasquill in which the rate of vertical dispersion is increased from the normal Pasquill-Gifford value to account for the turbulent entrainment of air during plume rise (Equation 4-4).

(Eq. 4-4) $$\sigma_z' = \sqrt{\sigma_z^2 + (\Delta h/3.5)^2}$$

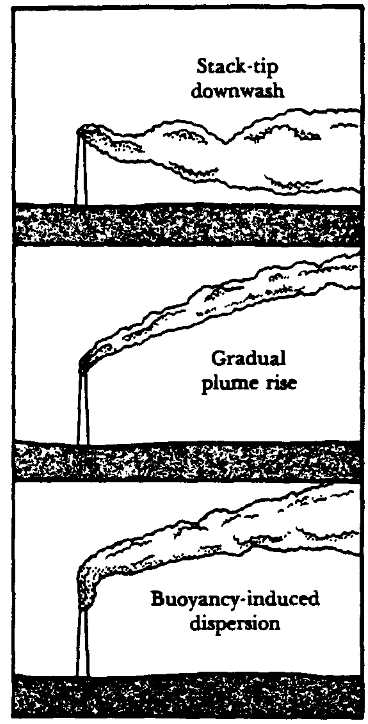


Figure 4-28. MPTER model options.

The MPTER model allows a total of 250 individual point sources and 180 receptor sites to be included in the calculations. The users can enter receptors at arbitrary locations of their choice. An option may be exercised to generate from one to five rings of receptors in a manner similar to the CRSTER model. As in CRSTER, the distance between receptor rings is at the user's discretion.

Receptors are placed at ground level, but may be on uneven terrain and are thus handled the same way as in the CRSTER model. Receptor heights on terrain features may be no higher than the top of the stack. The user should note, however, that the receptors must be placed no higher than the height of the **shortest** stack. For example, if three stacks with heights of 60, 80, and 100 meters were being analyzed, then the receptors could be placed no higher than 60 meters above the shorter stack base (see Figure 4-29).

Input for emission data and meteorological data are the same as the RAM model. Meteorological data required are hourly values of wind direction and speed, temperature, stability class, and mixing height. As in CRSTER and RAM, the Preprocessor program manipulates the meteorological data. Emission information consists of emission rate, physical height, stack diameter, stack-gas exit velocity, stack-gas temperature, and stack coordinates. The information required is the same as for other models already discussed, except for the stack coordinates. The coordinates are necessary so the model can properly locate and account for each of the sources.

$$\sigma_z' = \sqrt{\sigma_z^2 + (\Delta h/3.5)^2}$$

Given: $\sigma_z = 60$ m
$\Delta h = 300$ m

Calculate σ_z':

$$\sigma_z' = \sqrt{60^2 + (300/3.5)^2}$$

$$= \sqrt{3600 + 7346}$$

$$= \sqrt{10946}$$

$$= 104.62 \text{ (approximately 105)}$$

Example 4-5. Buoyancy-induced dispersion.

Limitations

The limitations of MPTER parallel those of the CRSTER model. However, MPTER is designed specifically for rural areas. It also will not treat building downwash, chemical transformations, removal, fumigation, or multiple pollutants.

Use and Output

EPA recommends MPTER for use in rural, multiple point source situations. MPTER is a refined analysis model with approximately the same execution costs as RAM. RAM should be run with the same care that was used to run MPTER. A sample of MPTER output is given in Figure 4-30. This model produces summary tables of the five highest 1-, 3-, 8-, and 24-hour concentrations at each receptor. Figure 4-30 gives the five highest 3-hour SO_2 concentrations at each receptor in a one-year period. The values shown are given in units of $\mu g/m^3$. The highest concentration in each column is indicated with a star to the left of it.

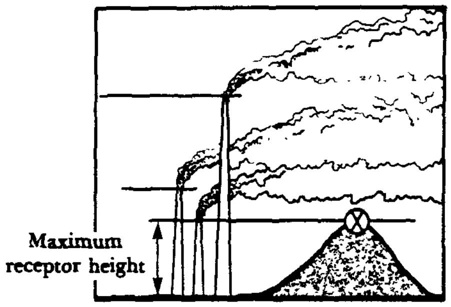


Figure 4-29. MPTER receptor height.

FIVE HIGHEST 3-HOUR SO2 CONCENTRATIONS(ENDING ON JULIAN DAY, HOUR)
(MICROGRAMS/M**3)

RECEPTOR			1	2	3	4	5
1(	.16,	.89)	900.19 (209,15)	787.78 (139,12)	629.74 (164,12)	537.63 (199,15)	501.94 (199,12)
2(	.31,	.85)	940.49 (139,12)	650.08 (164,12)	561.78 (207,12)	315.23 (209,15)	181.57 (199,15)
3(	.45,	.78)	631.37 (139,12)	589.07 (207,12)	265.43 (164,12)	179.00 (185,15)	81.84 (197,12)
4(	.58,	.69)	516.59 (185,15)	276.37 (207,12)	246.34 (202,15)	210.69 (139,12)	66.54 (160,15)
5(	.69,	.58)	691.91 (185,15)	316.99 (142,15)	258.80 (198,12)	187.56 (174,12)	99.08 (174,15)
6(	.78,	.45)	586.87 (198,12)	436.85 (185,15)	331.37 (174,12)	171.29 (142,15)	88.08 (174,15)
7(	.85,	.31)	629.96 (198,12)	250.15 (178,12)	117.23 (185,15)	115.46 (247,12)	106.82 (219,15)
8(	.89,	.16)	317.26 (198,12)	299.88 (136,12)	282.64 (219,15)	77.95 (174,12)	65.27 (210,15)
9(	.90,	.00)	577.23 (136,12)	301.13 (219,15)	62.00 (198,12)	77.02 (210,15)	29.95 (205,12)
10(	.89,	-.16)	563.75 (136,12)	216.18 (205,12)	142.64 (219,15)	37.97 (223,15)	30.77 (247,15)
11(	.85,	-.31)	553.03 (209,12)	332.92 (136,12)	86.59 (247,15)	75.94 (185,12)	62.62 (185,15)
12(	.78,	-.45)	631.47 (209,12)	435.96 (136,12)	324.04 (185,12)	316.37 (185,15)	268.52 (197,12)
13(	.69,	-.58)	684.14 (203,12)	682.10 (136,12)	677.48 (185,15)	643.00 (187,12)	603.18 (185,12)
14(	.58,	-.69)	1267.34 (203,12)	738.03 (187,12)	697.75 (185,15)	673.59 (142,12)	554.85 (136,12)
15(	.45,	-.78)	1231.91 (203,12)	780.45 (150,12)	744.22 (162,12)	441.58 (142,15)	389.07 (187,12)
16(	.31,	-.85)	608.43 (209,12)	588.70 (150,12)	354.55 (162,12)	347.03 (142,15)	273.96 (135,15)
17(	.16,	-.89)	323.33 (150,12)	296.28 (208,15)	131.96 (203,12)	120.12 (179,15)	111.08 (179,12)
18(	.00,	-.90)	552.55 (208,15)	127.17 (150,12)	48.71 (179,12)	38.49 (161,15)	35.29 (209,12)
19(	-.16,	-.89)	519.11 (208,15)	222.30 (163,15)	32.01 (204,12)	30.82 (168,15)	23.39 (150,12)
20(	-.31,	-.85)	809.88 (163,15)	226.89 (208,15)	172.15 (208,12)	88.95 (146,15)	40.09 (177,15)
21(	-.45,	-.78)	486.48 (167,15)	454.83 (209,12)	365.77 (186,15)	212.46 (228,15)	158.75 (207,15)
22(	-.58,	-.69)	620.61 (194,15)	530.55 (208,12)	408.80 (207,15)	474.78 (228,15)	368.64 (201,12)
23(	-.69,	-.58)	640.58 (207,15)	589.17 (222,15)	543.80 (201,12)	496.58 (146,15)	474.79 (228,15)
24(	-.78,	-.45)	609.90 (195,15)	550.37 (222,15)	539.76 (202,12)	528.38 (178,15)	511.58 (115,15)
25(	-.85,	-.31)	627.40 (177,12)	605.90 (163,15)	435.56 (115,15)	395.97 (202,12)	353.96 (179,12)
26(	-.89,	-.16)	695.58 (179,12)	687.11 (208,15)	500.69 (206,15)	472.77 (177,12)	324.97 (227,12)
27(	-.90,	.00)	716.01 (204,15)	604.21 (227,12)	572.56 (179,12)	548.16 (206,15)	183.90 (177,12)
28(	-.89,	.16)	533.87 (227,12)	396.28 (208,15)	289.75 (213,15)	276.52 (206,15)	231.53 (179,12)
29(	-.85,	.31)	330.48 (213,15)	217.91 (227,12)	97.58 (180,12)	94.42 (204,15)	91.12 (193,15)
30(	-.78,	.45)	181.87 (213,15)	161.63 (125,12)	146.19 (201,12)	145.28 (180,12)	118.16 (164,15)
31(	-.69,	.58)	604.60 (201,12)	597.49 (125,12)	527.81 (164,15)	381.87 (169,12)	304.19 (214,15)
32(	-.58,	.69)	840.60 (201,12)	833.38 (160,15)	813.71 (125,12)	717.56 (214,15)	229.17 (213,12)
33(	-.45,	.78)	812.07 (214,15)	639.97 (160,15)	550.08 (201,12)	539.60 (125,12)	288.34 (178,15)
34(	-.31,	.85)	843.12 (214,15)	408.29 (178,15)	379.78 (209,15)	301.44 (178,15)	224.49 (164,15)
35(	-.16,	.89)	1079.42 (209,15)	512.95 (199,12)	474.17 (199,15)	449.19 (193,12)	368.29 (178,15)
36(	.00,	.90)	* 1446.44 (209,15)	723.20 (199,12)	720.59 (199,15)	493.37 (193,12)	312.34 (139,12)
37(	.26,	1.48)	1108.56 (164,12)	777.93 (139,12)	691.01 (209,15)	411.21 (193,12)	356.83 (199,12)
38(	.51,	1.41)	1189.07 (164,12)	1095.46 (139,12)	565.81 (207,12)	391.06 (126,12)	374.01 (209,15)
39(	.75,	1.30)	880.26 (139,12)	742.92 (207,12)	637.97 (197,15)	534.86 (125,12)	499.30 (164,12)
40(	.96,	1.15)	1067.52 (137,15)	1015.65 (195,15)	1008.45 (161,12)	956.40 (197,15)	837.69 (61,18)
41(	1.15,	.96)	1190.03 (65,6)	883.92 (142,15)	647.76 (84,12)	645.43 (145,15)	617.32 (260,15)
42(	1.30,	.75)	764.13 (174,12)	661.16 (247,12)	587.47 (143,12)	521.56 (210,12)	517.28 (198,12)
43(	1.41,	.51)	824.75 (247,12)	589.18 (198,12)	550.96 (139,15)	492.55 (174,12)	411.26 (143,12)
44(	1.48,	.26)	859.77 (219,15)	463.40 (247,12)	375.59 (198,12)	322.83 (136,12)	306.57 (156,12)
45(	1.50,	.00)	946.23 (219,15)	649.23 (136,12)	250.07 (156,15)	243.05 (156,12)	195.92 (222,15)
46(	1.48,	-.26)	613.06 (136,12)	574.40 (219,15)	329.29 (247,15)	230.20 (205,12)	212.29 (156,15)
47(	1.41,	-.51)	840.26 (247,15)	946.96 (205,12)	573.71 (162,15)	442.93 (155,12)	422.66 (223,15)
48(	1.30,	-.75)	835.54 (247,15)	739.96 (162,12)	721.45 (185,12)	694.57 (205,12)	638.93 (155,15)
49(	1.15,	-.96)	924.76 (187,12)	814.93 (136,12)	790.87 (185,12)	794.63 (205,15)	700.30 (203,12)
50(	.96,	-1.15)	1125.55 (203,12)	* 1112.90 (187,12)	817.35 (203,15)	697.96 (91,18)	677.42 (198,15)
51(	.75,	-1.30)	940.67 (203,12)	766.95 (142,15)	643.83 (150,12)	567.31 (142,12)	516.75 (227,15)
52(	.51,	-1.41)	609.85 (142,15)	506.25 (150,12)	408.76 (203,12)	268.66 (291,12)	265.46 (179,15)
53(	.26,	-1.48)	798.97 (150,12)	714.67 (179,12)	557.54 (204,15)	535.53 (179,15)	529.50 (204,12)
54(	.00,	-1.50)	866.92 (208,15)	613.09 (208,12)	556.01 (150,12)	443.75 (179,12)	354.94 (221,12)

Figure 4-30. MPTER output.

Review Exercise

1. The MPTER allows dispersion estimates to be made at elevated receptors by using a. Holland's plume rise. b. the CRSTER method of terrain adjustment. c. polar coordinates. d. terrain downwash. e. final plume rise.	
2. True or False? MPTER will calculate concentrations in uneven, rural terrain.	1. b. the CRSTER method of terrain adjustment.
3. Three technical options available with MPTER are ________, ________, and ________.	2. True
4. True or False? MPTER will allow either Holland's or Briggs' plume rise methods.	3. stack-tip downwash, gradual plume rise, buoyancy-induced dispersion
5. MPTER adjusts wind speed by a a. linear extrapolation. b. user estimation. c. power law formula. d. ratio of gas velocity to atmospheric stability. e. Gaussian formula.	4. False
6. True or False? MPTER can treat complex terrain.	5. c. power law formula.
7. The MPTER is a ________ plume model.	6. False
8. True or False? The MPTER model calculates plume rise using gradual plume rise only.	7. Gaussian
9. The MPTER model allows a total of ________ point sources and ________ receptor sites per run.	8. False
10. True or False? The MPTER can generate a circular set of five receptor rings just as the CRSTER model does.	9. 250, 180
11. The MPTER model is recommended by U.S. EPA for modeling pollution sources in a. rural situations. b. complex terrain. c. urban situations. d. Texas.	10. True
	11. a. rural situations.

Lesson 7
VALLEY

Supplementary Reading

For more information about the VALLEY model and its methods of treatment, obtain a copy of EPA 450/2-77-018, *VALLEY Model User's Guide,* September 1977.

Lesson Goal and Objectives

Goal

To familiarize you with the VALLEY model, its method of making dispersion estimates at receptor sites located on terrain higher than stack top, and how it calculates worst-case air pollution concentration.

Objectives

Upon completing this lesson, you should be able to:
1. identify the VALLEY model plume characteristics.
2. list the limitations of the VALLEY model.
3. describe the worst-case meteorological conditions used with the VALLEY model for estimating the maximum short-term concentration in complex terrain.
4. state the regulatory use of the VALLEY model.

Introduction

The last model to be discussed is the VALLEY model. As shown in Figure 4-31, it is also known as the complex terrain model. It was designed to allow modelers to estimate pollution concentrations at receptors located above stack height. The CRSTER and MPTER models handle terrain up to the lowest stack height. If receptors are located on terrain above the height of the stacks (shown as "x"), these models cannot be used. Therefore, a reasonably accurate technique to estimate air quality in complex terrain is needed, and VALLEY was developed to fill this gap. Efforts to create an accurate complex terrain model are far from over, and EPA is in the midst of developing an extensive complex terrain model. However, a

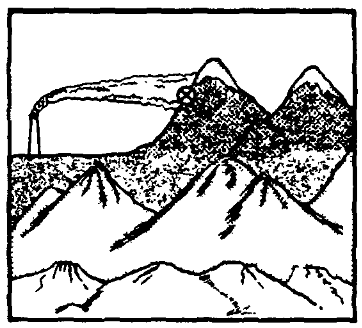


Figure 4-31. Complex terrain model.

refined model isn't expected to be available for several more years. In the interim, VALLEY is an approved screening technique for complex terrain.

Complex Terrain

Complex terrain influences the trajectory and diffusion of a plume. The adverse effects of complex terrain are well known. First, concentrations are increased because of the proximity of elevated ground to the plume centerline. In extreme cases, the plume can sometimes directly impact the side of a hill. Second, drainage flow from mountain slopes at night causes air to pool and stagnate in the valleys, and high concentrations often result. Yet, there are physical processes acting that also tend to lower concentrations. Field studies have shown that winds tend to follow the terrain instead of going across steep height gradients. This is called *channelization,* and it reduces the chances for plume interaction with elevated terrain. In addition, the increased turbulence from complex terrain will often lead to lower concentrations at distances farther downwind.

The focus of concern in complex terrain is on the near field receptors close to a source where very high concentrations can often occur. Potential flow theory and field studies indicate that plume impaction will most likely occur under stable atmospheric conditions (Pasquill-Gifford Class E or F). The kinetic energy required by a fluid to overcome the temperature inversion and rise up over the terrain is not available. EPA has analyzed field data from several sites in the Rocky Mountains and determined that a reasonable set of worst-case meteorological conditions for short-term concentrations in complex terrain is Class F stability, a wind speed of 2 to 5 m/s and persistence of the wind direction within a 22½° sector for 6 hours in a 24-hour period. These are the meteorological conditions that EPA recommends be used in the VALLEY model to estimate maximum 24-hour concentrations in complex terrain.

Plume Characteristics

Since the VALLEY model is a Gaussian plume model, conditions are assumed to be steady state. That is, the atmosphere and source conditions are constant over an averaging period. The plume height is calculated by Briggs' method, and the gradual rise option is recommended for complex terrain calculations. In addition, the option of buoyancy-induced dispersion is appropriate in complex terrain. In unstable atmospheric conditions, the plume height is constant over terrain. In stable atmospheric conditions, the plume height is constant above sea-level elevation, and the plume centerline is allowed to come as close as 10 meters to the surface of the ground, as shown in Figure 4-32.

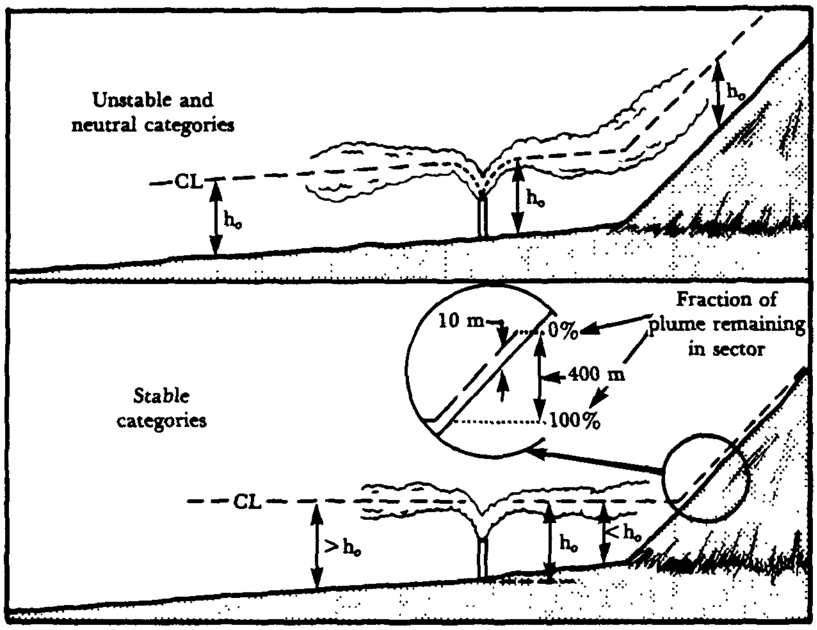


Figure 4-32. VALLEY model treatment of terrain.

Input Parameters

The basic model allows a total of 50 point and area sources that can be assigned to any locations to evaluate impact at a fixed network of 112 receptors. The receptor network is defined by 16 radials and seven equally spaced ring distances. The user must scale the receptor from a known map scale. The user must have a U.S. Geological Survey topographical map (1:24,000 scale) to be able to properly assign receptor heights from stack bases. The meteorological data recommended for use with VALLEY are the worst case conditions discussed above. Alternative inputs may be specified using guidance in the *User's Guide*.

Limitations

The VALLEY model is designed to simulate a specific worst-case condition in complex terrain, namely that of plume impaction under stable atmospheric conditions. During unstable conditions, it will tend to underpredict concentrations. The model is also not designed to simulate terrain downwash, fumigation, changes in wind field trajectories, or stagnant air conditions. Finally, the VALLEY model results are only valid for receptors on the front of the first ridge of complex terrain encountered by a plume. Behind the first hill and farther downwind, the VALLEY model results are unreliable.

Use and Output

VALLEY can be used as a screening model in urban or rural areas. It is recommended for use in rural areas where concentration estimates are required at receptor sites in complex terrain. The averaging times available are 24-hour and annual averages. The primary use is to estimate 24-hour averages using a set of predetermined meteorological conditions: Class F stability, a wind speed of 2.5 m/s and wind directional persistence for 6 hours in a 24-hour period. The output from VALLEY is very difficult to read and interpret. An example is shown in Figure 4-33 and concentration isopleths have been drawn in as an aid.

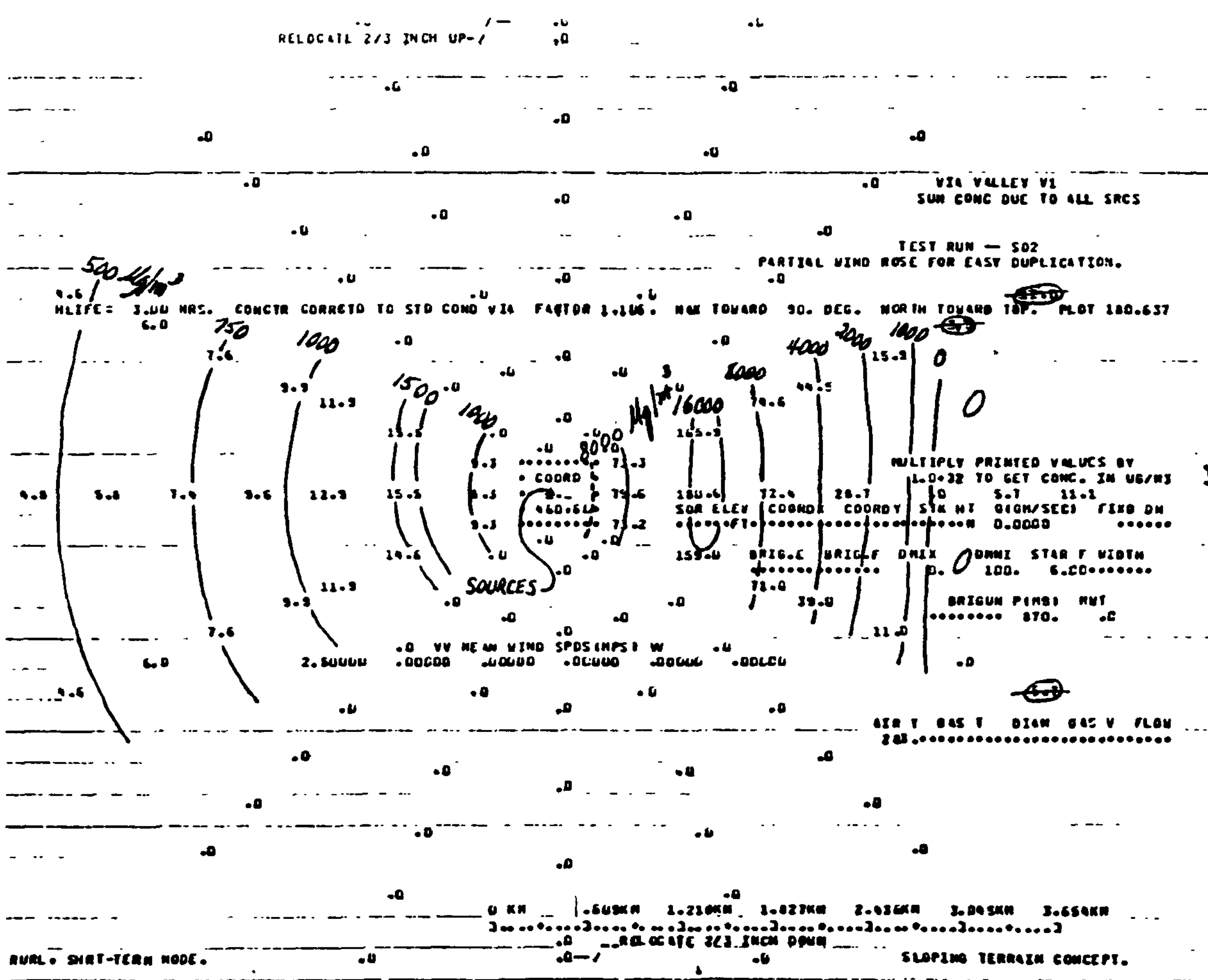


Figure 4-33. Output of test run for SO_2 using VALLEY.

Review Exercise

1. True or False? The VALLEY model is a refined complex terrain model.	
2. True or False? The VALLEY model will give valid concentration estimates behind hills.	1. False
3. Which of the following is(are) a limitation of the VALLEY model? a. It cannot handle more than one source. b. It underestimates plume rise. c. It only treats building downwash. d. It underestimates concentrations for unstable conditions (Classes A through D). e. It underestimates concentrations for stable conditions (Classes E through F).	2. False
4. EPA has found that maximum short-term concentrations in complex terrain are most likely to occur under a. unstable atmospheric conditions. b. stable atmospheric conditions. c. very high winds. d. wind channelization. e. the old oak tree.	3. d. It underestimates concentrations for unstable conditions (Classes A through D).
5. The worst-case meteorological conditions that should be used with VALLEY are Class ________ stability, a wind speed of ________, and wind directional persistance in a 22½° sector for ________ hours during a 24-hour period.	4. b. stable atmospheric conditions.
6. The VALLEY model will handle receptors located a. only at ground level. b. only up to stack-top height. c. in urban situations only. d. from ground level to above stack top.	5. • F • 2.5 m/s • 6
7. In stable atmospheric conditions, the VALLEY model allows the plume centerline to come how close to the ground-based receptor? a. 100 meters b. 400 meters c. 0 meters d. 10 meters	6. d. from ground level to above stack top.
8. True or False? VALLEY is the approved EPA screening model for receptors in complex terrain.	7. d. 10 meters
	8. True

Unit 5
Practical Use of Point Source Atmospheric Dispersion Models

Lesson 1
Receptor Siting

Lesson Goal and Objectives

Goal

To familiarize you with the procedures involved in siting receptors for determining downwind pollution concentrations.

Objectives

Upon completing this lesson, you should be able to:

1. explain the relationship between an air quality model and a receptor location.
2. describe the criteria for siting an air quality receptor.
3. explain the difference between guessing where receptors should be placed and making educated guesses for the same placement.
4. name one statistical method and its technique for locating receptor sites.
5. explain the reason the PTDIS and PTPLU models might be chosen to select receptor sites.
6. explain the procedure that uses PTDIS and PTPLU to find the distance to maximum ground-level concentrations.
7. explain what is meant by a receptor site being called semipermanent.
8. state the number of receptor sites found in the CRSTER single-source model.
9. recognize the reason the RAM model's output can be meaningless for time periods longer than 1 hour.

Introduction

All air quality models discussed in Unit 4 estimate pollution concentrations at points downwind from the source, called receptors. Air quality modelers are interested in determining what the concentration of a pollutant will be after it is transported and dispersed by the atmosphere to specific locations. The locations of interest might be in a city, rural area, or national park (Figure 5-1).

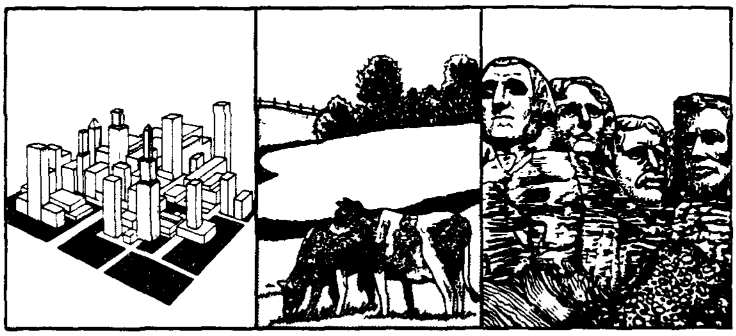


Figure 5-1. Areas of environmental concern.

Concern might center on public health or property damage (Figure 5-2). Whatever the reason for modeling, the user will want to place the receptors where maximum concentrations are likely to occur and the general public has access. The locations for receptors may already be determined before modeling begins. It may be necessary to find out if the air quality of a specific area exceeds the National Ambient Air Quality Standards (NAAQS). In that case, the receptor site is not arbitrarily chosen by the air quality modeler. In many instances, however, the most appropriate sites for receptors are not known in advance. For instance, the modeler's interest may be in the location and magnitude of the maximum concentrations so that air quality samplers might be placed there (Figure 5-3). As indicated above, any number of air quality decisions might depend on the outcome of the model. Consequently, receptor siting is not a trivial matter.

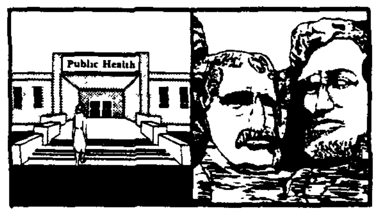


Figure 5-2. Health effects and property damage.

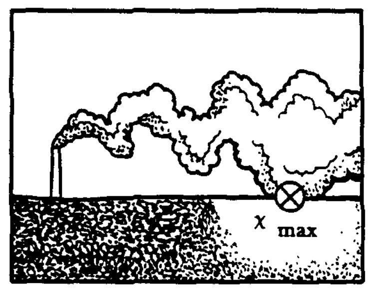


Figure 5-3. Maximum concentration location.

Guessing

Receptor siting may be accomplished by using a number of approaches. One approach, used at times by the most experienced air quality modeler, is guessing. Of course, guessing assumes different levels of accuracy, depending on the individual guessing. For instance, a receptor site chosen by an individual who has no experience in air quality modeling can properly be called a guess. An individual's prior experience in such factors as terrain influence, meteorology, source characteristics, and specific air quality models increases the chance that the receptor site chosen is more appropriate. A selection by this individual is called an "educated" guess (Figure 5-4). Guessing may at times be the only approach available to site receptors.

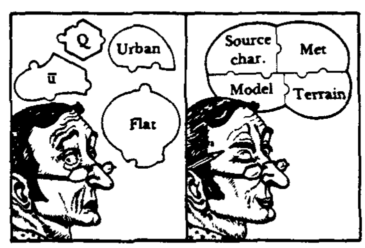
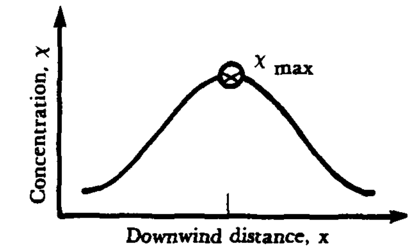


Figure 5-4. Guessing vs. educated guessing.

Math Procedures

A second approach may appear to be more scientifically sound because a mathematical procedure is used. The procedure can range from using a graph to using statistical probabilities in a complex formulation (Figure 5-5). Obviously, this approach involves some cost to the user. As the procedure becomes more complex, the cost increases because of the amount and accuracy of the required data. Statistical probability methods such as frequency of occurrence or the Monte Carlo method are used. A method like the frequency of occurrence depends on knowledge of historical events such as wind direction and stability class. Monte Carlo techniques involve the use of random numbers to determine the most likely places for maximum concentrations and, hence, the best places for receptors to be sited.

Monte Carlo methods (Figure 5-6) are used for applications where no mathematical solution to a problem exists. Given that a complex statistical method may be employed in a model for siting receptors, the model may not be as consistently accurate as educated guesses by an experienced air quality modeler.



$$\frac{d\chi}{dt} = \frac{\Delta}{\Delta_x}\left(K_x \frac{\Delta\chi}{\Delta_x}\right) + \frac{\Delta}{\Delta_y}\left(K_y \frac{\Delta\chi}{\Delta_y}\right) + \frac{\Delta}{\Delta_z}\left(K_z \frac{\Delta\chi}{\Delta_z}\right)$$

Figure 5.5 Graph and complex formula for plume dispersion.

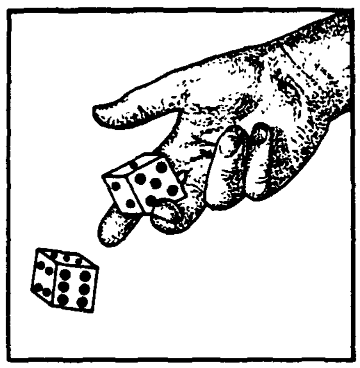


Figure 5-6. Monte Carlo method.

Screening Models

Another approach to receptor siting is to use the output of a screening model to define the locations for receptors in subsequent runs of either a refined or screening model.

The PTPLU model is ideally suited to this task since it gives the downwind distance of the maximum concentration from a point source under a variety of conditions. One procedure used is to find the highest concentration predicted by PTPLU for each of the six stability Classes A through F, then identify the downwind distances of the maxima from the PTPLU output (Table 5-1). These six distances can then be used to locate receptor rings in a refined model such as CRSTER, MPTER, or RAM. The PTDIS screening model can also be used to help select receptor sites. PTDIS allows the user to specify a number of downwind distances for the purpose of generating the profile of concentrations from a point source. By running the model a number of times, the maximum concentration and its location can be "cornered." U.S. EPA recommends using inexpensive, simple screening models, like PTPLU or PTDIS models, for determining maximum ground-level concentrations and the distances to them before using a more expensive refined model.

Table 5-1. PTPLU output can be used to select receptor ring distances.

Stability class	Max. conc.	Distance (km)
A	1661	1.15
B	802	2.73
C	611	4.34
D	214	9.72
E	179	12.21
F	98	25.40

Semipermanent Receptor Site Models

Other air quality models have semipermanent receptor sites that are generated internally for the user. Being semipermanent means that the number of receptors and their direction from the source are fixed. The distances away from the source are not fixed and can be varied through several runs to find the location of maximum concentrations.

The user may select the distances as needed. Because the wind direction at a specific source is variable throughout the year, the receptor sites are generally placed in circular rings around the source. This differs from the PTXXX models, which site receptors in a straight line. For example, Figure 5-7 shows the CRSTER with 180 receptor sites available on five circular rings, and Figure 5-8 shows the VALLEY with 112 receptor sites in seven circular rings.

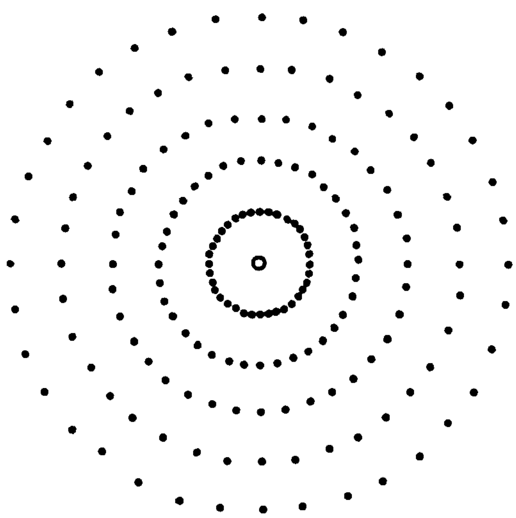


Figure 5-7. CRSTER receptor rings.

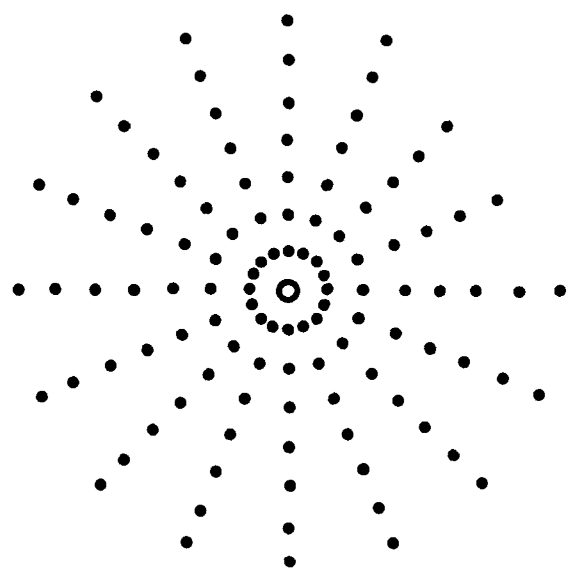


Figure 5-8. VALLEY receptor rings.

For siting receptors, individual runs for these models are more expensive than runs for the simpler PTXXX models. For example, if a source and 50 receptors are to run in the PTDIS model, the output will cost approximately $1.50. However, if 180 receptors, 19 sources, and one year of meteorological data are run in the CRSTER, the output may cost $50.00. A point to remember is that cost of model output is directly related to the model's complexity. Factors such as the amount of meteorological data, number of sources (area and point), and volume of output all affect the cost.

RAM Model Receptor Site Option

Guessing, using statistical probability procedures, or using internally generated semipermanent receptor sites complicates receptor siting. These factors complicate siting because, unless enough runs identify maximum concentrations, the accuracy of the siting is uncertain. The RAM multisource model has an option available that can help: program-selected receptors (Figure 5-9). When used, this option allows the model to locate receptor points where it predicts the maximum concentration will occur for a given hour. Since the winds change each hour, the program-selected receptors will also change locations. Thus, output for these receptors for averaging times greater than one hour is meaningless, since the point was not fixed in space.

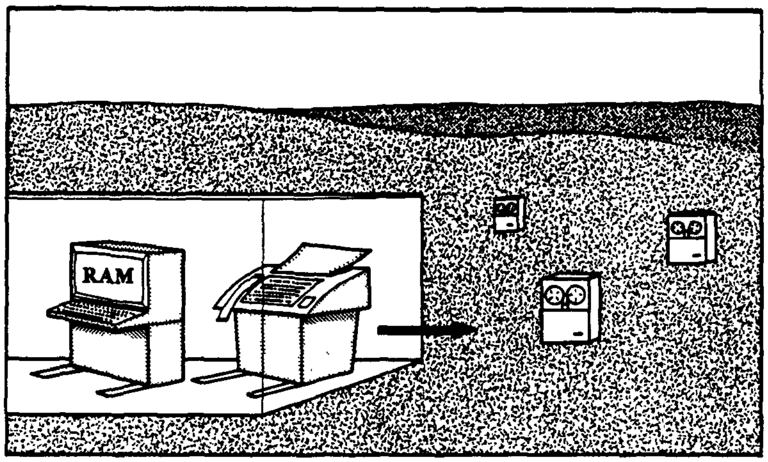


Figure 5-9. RAM receptor siting option.

Review Exercise

1. The relationship between an air quality model and a receptor is that a. an air quality model always computes a distance to the receptor locations. b. receptors are always in urban areas because air quality models are **only** concerned with health effects. c. both are **always** arbitrarily chosen. d. an air quality model estimates pollution concentrations at points called receptors.	
2. Receptor sites should be located where ________ are expected to occur and ________ has access.	1. d. an air quality model estimates pollution concentrations at points called receptors.
3. Choose one statistical method and its technique used in siting receptors. a. Monte Carlo, random numbers b. hypergeometric, exponential decay c. Weibull, normal distribution d. poisson, geometric	2. maximum concentrations, the general public
4. The PTPLU and PTDIS models might be chosen to select receptor sites because they are a. refined air quality models. b. inexpensive and simple screening tools. c. recommended by U.S. EPA. d. both b and c	3. a. Monte Carlo, random numbers
5. The PTPLU model is ideally suited for selecting receptors because a. it is a statistical technique. b. it is a highly sophisticated model. c. the general public has access to it. d. it gives the distance to the maximum concentration for each stability class.	4. d. both b and c
6. When an air quality model's receptor sites are of a fixed number and direction from the source they are called ________.	5. d. it gives the distance to the maximum concentration for each stability class.
7. The CRSTER single-source model has ________ receptor sites on ________ circular rings.	6. semipermanent
	7. 180, 5

8. The RAM model's output may be meaningless for averages longer than one hour because
   a. RAM only produces hourly output.
   b. program-selected receptor sites will change location every hour.
   c. RAM's output is only for 24-hour periods.
   d. the RAM model divides 24-hour concentrations into eight, 3-hour periods.

8. b. program-selected receptor sites will change location every hour.

Lesson 2
Roughness Length and Terrain Adjustment

Lesson Goal and Objectives

Goal

To familiarize you with the effect of small surface roughness features and large terrain features on wind flow and with how certain models use roughness length and are modified for applications in complex terrain. The adjustment methods of the CRSTER and MPTER models, and the special problems of the VALLEY model in describing concentrations in complex terrain will also be covered.

Objectives

Upon completing this lesson, you should be able to:

1. describe the effect of natural and artificial objects on wind flow.
2. define roughness length.
3. recognize the difference between roughness features and terrain features.
4. name three UNAMAP models that can be adjusted for terrain.
5. name the model that was designed for rough, mountainous terrain.
6. describe the method used by the CRSTER and MPTER models to adjust for terrain that may extend up to the height of the stack.
7. state one reason that the VALLEY model may perform poorly in its attempt to describe pollution concentrations in complex terrain.
8. describe the method the EPA models use to adjust for terrain lower than stack base.

Roughness

Roughness is a function of surfaces of objects on the earth such as buildings, trees, bridges, etc. Each object, whether natural or artificial, slows and distorts the direction of the free wind due to its height, shape, and surface characteristics. Roughness features are usually relatively small, such as grass, trees, and houses. These features affect the wind pattern, particularly the wind speed as it approaches the earth's surface, by causing frictional drag in the lower atmosphere (Figure 5-10).

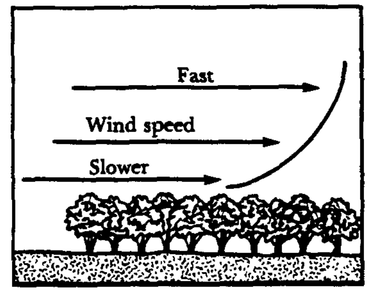


Figure 5-10. Roughness effect on wind flow.

Roughness Length

Roughness length is defined as the height above ground when the mean wind speed goes to zero due to frictional effects. Some roughness length considers the earth's texture (objects in the path of the wind), it is graded in a manner similar to the way sandpaper is graded—from smooth to rough (Figure 5-11). Some typical values for z_o are given in Table 5-2. Notice that the roughness length for a desert is 0.03 cm. This means that the wind speed declines to zero very close to the earth because a desert is relatively smooth. Since an urban park has objects extending higher off the ground, the wind is blocked or slowed to zero farther from the ground, so roughness length is higher.

Table 5-2. Typical values of roughness length.

Surface	z_o (cm)
Desert	0.03
Alfalfa field	2.72
Corn field	74
Urban park	127
Central business district	321

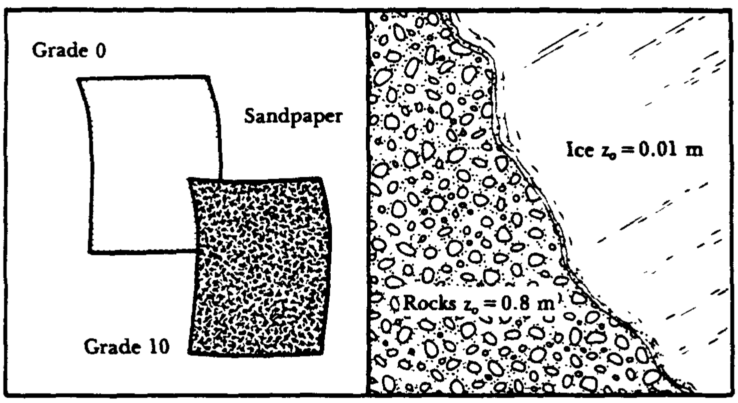


Figure 5-11. Sandpaper grade analogy for roughness factors.

Inclusion of Roughness Length in Air Quality Models

Roughness length is represented in air quality models by the set of dispersion rates that are used. z_o is a measure of turbulence and dispersion is increased by turbulence. Therefore, the greater the value of z_o, the faster a plume will spread in the vertical and horizontal directions. The Pasquill-Gifford dispersion curves used in most EPA models are based on a few carefully performed diffusion experiments from the 1950s. The terrain in these cases was rural, gently rolling, and z_o ranged from 3 to 30 cm. By contrast, the McElroy-Pooler dispersion experiments, on which the urban RAM model is based, were performed in an environment downwind of a city where z_o equalled 100 cm. The larger roughness length reflects the increased turbulence found in urban areas.

Terrain Adjustments

Terrain features differ in size from roughness elements (Figure 5-12). Terrain is usually considered to be large surface features, such as mountains and hillsides. Roughness elements, which are relatively smaller, slow the wind through frictional drag and usually affect only the edges of the plume. Terrain, however, affects the entire plume by distorting wind flow (Figure 5-13). The adjustment to models for terrain provides information about plume behavior. The information is used in the model to predict ground-level concentrations downwind. Terrain adjustment is concerned with the resulting path of the plume centerline with respect to large terrain features.

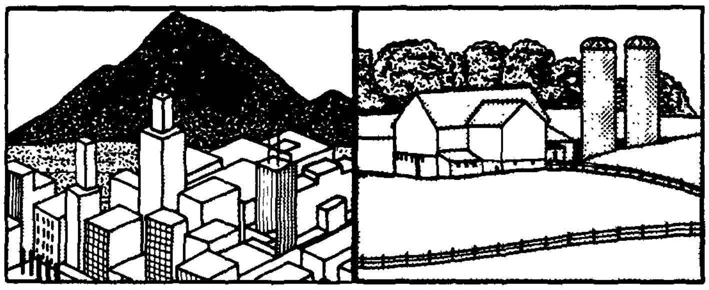


Figure 5-12. Terrain and roughness features.

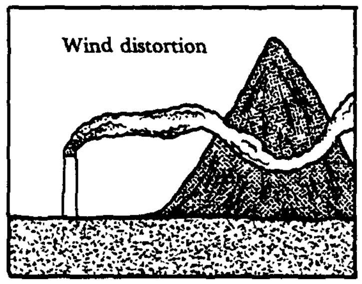


Figure 5-13. Terrain effect on wind flow.

CRSTER

As shown in Figure 5-14, the CRSTER model uses simple terrain adjustments. Terrain adjustments are either simple or complex. The CRSTER model will not estimate concentrations at receptors on terrain that is higher than the stack top. That is, the difference between the height of a receptor on terrain and the stack top is calculated using the base elevation of the stack. The highest terrain considered can be no taller than the physical height of the stack. If more than one stack is grouped

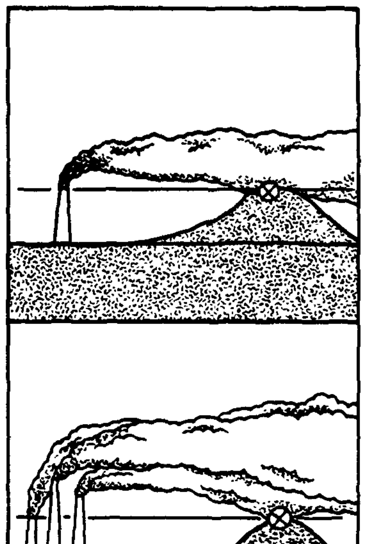


Figure 5-14. CRSTER terrain adjustments for receptor heights.

in a location, then the shortest stack of the group is used to determine the terrain height limit. For example, in Figure 5-15, if the stack is located on terrain that is 400 meters above sea level and the stack is 60 meters high, the model would not estimate concentrations at receptors higher than 460 meters above sea level.

Areas of terrain that are lower than stack base may be included, as shown in Figure 5-16. Any receptor lower than stack base is automatically raised by the model to stack base elevation. For example, if the stack base is at zero elevation, a receptor lower than stack base would have a negative elevation. A receptor 10 meters below the stack base would be entered as a minus 10. The model would raise the elevation of such a receptor up to zero.

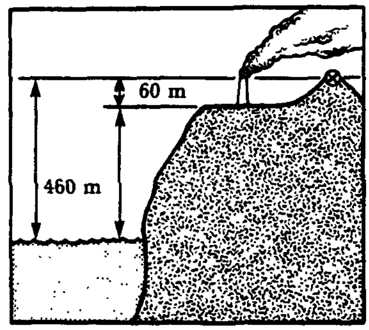


Figure 5-15. Receptor height example.

The user should remember that pollutant concentrations increase as the elevated terrain approaches the plume centerline. As discussed earlier, terrain adjustments in the Gaussian model are made by decreasing the effective plume height, H. This can be thought of as the plume centerline remaining level and the terrain rising up toward it. In reality, the terrain adjustments are made, not by raising the receptors, but by lowering the plume centerline so that the plume is moved closer to the receptor. The effect on concentration is the same either way.

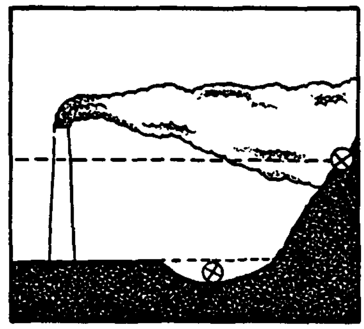


Figure 5-16. CRSTER adjustment for depressions.

MPTER Adjustment

The MPTER model's terrain adjustment goes beyond CRSTER's by allowing the user to decide how the plume will travel over the terrain feature. The adjustment may be chosen from 0 to 1, or from 0% to 100% (Figure 5-17). If zero adjustment for terrain is called for, then the MPTER model will keep the plume centerline height constant above the terrain. This means that the plume will follow the terrain shape. If 100% adjustment is called for, then MPTER will adjust for terrain as previously described for CRSTER. In MPTER, the user may elect to use any percent of adjustment between 0 and 100% that is deemed necessary. MPTER, with this adjustment option, is more complex than CRSTER, but less complex than the VALLEY model, which is described next.

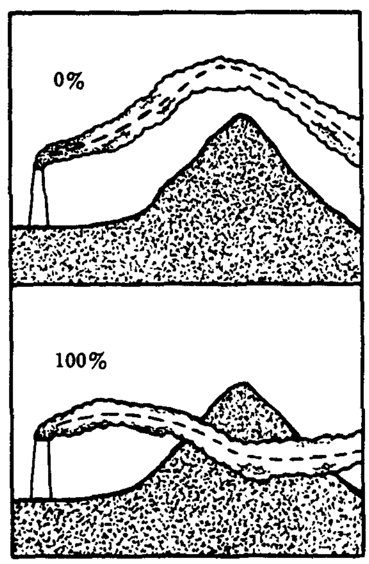


Figure 5-17. Variable terrain adjustment for MPTER.

VALLEY Adjustment

The VALLEY model is called the complex terrain model. It was designed to adjust for terrain by using more complex methods than the CRSTER. VALLEY is also a Gaussian plume model. All of the assumptions inherent in using the Gaussian distribution still apply.

VALLEY was designed for complex terrain—that is, rough, mountainous areas. It was developed using sparse data from the western U.S. The model adjusts plume behavior for terrain (Figure 5-18). It considers plume centerline behavior as a function of two atmospheric stability situations. These situations are stable (Pasquill-Gifford stability Classes E and F) and unstable/neutral (P-G Classes A through D).

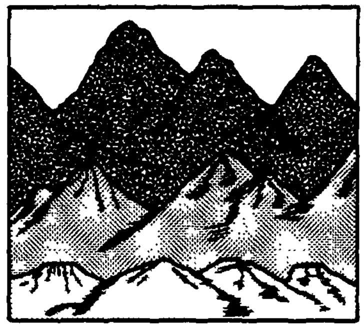


Figure 5-18. Complex terrain, or VALLEY.

For stable atmospheric conditions, VALLEY assumes the plume centerline is located at the height calculated by Briggs' plume rise equation plus the physical stack height. This height is called effective stack height. The plume centerline is then assumed to stay at a constant height above stack base. This means that if the terrain increases in elevation downwind from the source, the plume centerline will approach the ground. In effect, the distance from the plume centerline to the ground becomes smaller. The model will not allow the plume centerline to actually impact the terrain. It maintains a 10-meter minimum separation between the plume centerline and the terrain beyond the first point where the centerline comes within 10 meters of the terrain. If the terrain continues to increase in elevation, the plume maintains the 10-meter separation as it spreads vertically for 400 meters, at which point the concentration is assumed to have decreased to zero.

For neutral and unstable atmospheric conditions, the model assumes that the plume centerline remains constant above ground level. This means that no matter what the terrain features are downwind of the source, the plume follows the shape of the terrain.

The user should note, however, that the concentration estimates should be ignored after the plume first comes in contact with any part of a hill (Figure 5-19). This is because VALLEY does not incorporate increased turbulence on the backside of hills, ridges, etc. The VALLEY model may perform poorly in making concentration estimations in complex terrain. This is because the Gaussian distribution concepts have been considerably modified in the attempt to handle complex terrain. Unfortunately, the effects of complex terrain have not been studied thoroughly enough to develop a technique that performs significantly better than VALLEY in estimating the highest concentrations that are of concern to regulatory agencies.

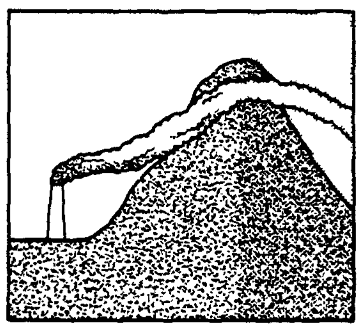


Figure 5-19. Terrain limitations for VALLEY.

Review Exercise

1. Define roughness length.	
2. The effect of natural and manmade objects on wind flow near the surface of the earth is to a. increase the wind speed and direction. b. slow and distort the wind. c. reduce frictional drag. d. both a and c	1. Roughness length is the height above the ground where the mean wind speed goes to zero due to frictional effects.
3. The typical roughness length assumed in the urban RAM model is a. 100 cm. b. 100 m. c. 10 m. d. 1 cm.	2. b. slow and distort the wind.
4. Three UNAMAP models that can be adjusted for terrain such as hills are a. CRSTER, ELSTAR, VALLEY b. VALLEY, RAM, CDM c. CRSTER, RAM, ELSTAR d. CRSTER, MPTER, VALLEY	3. a. 100 cm.
5. The one UNAMAP model designed for complex terrain, such as large mountains, is a. CRSTER b. CDM c. VALLEY d. RAM	4. d. CRSTER, MPTER, VALLEY
6. The simple terrain adjustment method used by models such as CRSTER is to a. decrease the effective plume height by the rise of terrain above stack base. b. count hills and multiply by that number. c. lower hill tops to stack base height. d. raise stack base to hill tops.	5. c. VALLEY
7. One reason VALLEY may perform poorly in estimating concentrations in complex terrain is that a. VALLEY does not use the Gaussian distribution. b. turbulent effects over terrain are well understood. c. the Gaussian distribution is severely modified. d. it was designed for flat terrain only.	6. a. decrease the effective plume height by the rise of terrain above stack base.
	7. c. the Gaussian distribution is severely modified.

8. The method used by models to adjust for terrain lower than stack base is to
   a. supply pollution material to the model equal to the area of the sink holes.
   b. lower the stack base until it is level with the bottom of the hole.
   c. lower the stack top by an amount equal to the depth of the deepest depression.
   d. raise the terrain to the level of the stack base.

8. d. raise the terrain to the level of the stack base.

Unit 6
Case Studies: Modeling and Interpreting Results

Lesson 1
Oil Refinery

Lesson Goal and Objectives

Goal

To familiarize you with an actual case of modeling the air quality surrounding an oil refinery and interpreting the results of that modeling.

Objectives

Upon completing this lesson, you should be able to:

1. describe the terrain features around the oil refinery.
2. describe the new proposed construction.
3. name the model chosen.
4. identify why the oil refinery was "screened" first, instead of using a refined analysis.
5. interpret the results of modeling by correctly identifying the maximum ground-level concentrations given by the model run.

Introduction

We've looked at several air quality models found on UNAMAP, Version 4—particularly the point source dispersion models that are Gaussian plume models. Each model is designed for specific air pollution applications. Screening models are designed to be simple, for fast calculations of pollution concentration estimates. Other complex models examine the details of atmospheric and industrial processes and their interactions in an attempt to estimate pollutant concentrations. Each user must decide which kind of model to use for any specific application. Each situation tends to be site-specific. A model that produces acceptable results in Oklahoma City may not perform as well in Dallas. The situations are different, even though both are large cities located on flat terrain.

The user may seek advice from a professional air quality modeler, air quality meteorologist, or U.S. EPA as to the appropriate model to use. For example, the single-source CRSTER model would not be appropriate for widely-spaced pollution point sources since it locates all sources at a single plant site. A flat terrain model, such as RAM, would not be selected for a problem in complex terrain. Again, the PTXXX models were designed for flat terrain and Gaussian plumes. If a large body of water is added to the situation, the models may not perform well due to shoreline effects.

Oil Refinery Case Study

One case study to be examined is an oil refinery located in northeastern Oklahoma. The oil company plans to expand the existing facilities to increase its capabilities. While some renovation of the existing facilities will take place, the refinery will not stop operating. The refinery currently operates 24 hours per day. It will continue this schedule after renovation and expansion of the facilities. Except for a few farmers, most of the population living around the refinery work directly or indirectly for this oil company. Factors to be considered are listed in Figure 6-1.

Physical layout of industry site
Problem
Meteorological situation
Selected model
Reasons for selection
Output

Figure 6-1. Considerations for case studies.

Description of the Area

The northeastern section of Oklahoma (Figure 6-2) can be described as fairly flat, with some elevations up to 10 meters above the surrounding terrain. Most of the area is forested. Some gravel pits and coal strip mines dot the area. A few oil wells are also within the area. Small streams cross the area, and a river runs north to south by the western edge of the refinery. A major four-lane highway and a railroad serve the area. A small lake is located south-southeast of the refinery. A small town is located 1 kilometer east of the plant. A large urban area is located 24 kilometers southwest of the refinery.

Description of the Plant Site

The plant site has an elevation of 173 meters (567 feet) above mean sea level (MSL) and is situated in a relatively flat river valley. At a distance of 1.25 kilometers northeast, the terrain rises 10.1 meters (33 feet) above stack base. The plant site occupies about 90 acres of land. An area 1 kilometer to the southwest is 8 meters (26 feet) lower than stack base.

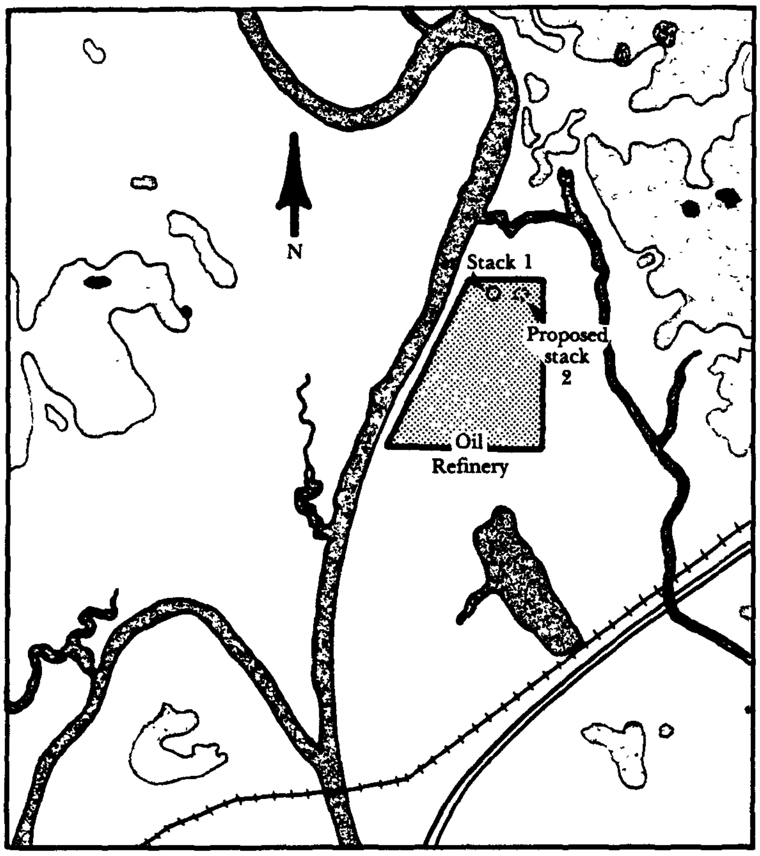


Figure 6-2. Northeastern Oklahoma.

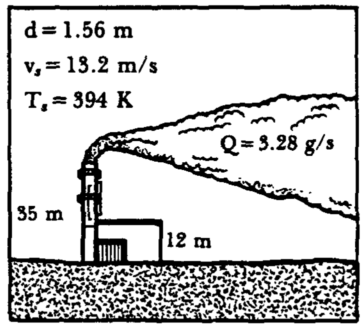


Figure 6-3. Refinery: existing conditions.

Description of the Oil Refinery

Figure 6-3 includes the refinery with one existing stack that emits 3.28 grams per second (114 tons per year) of sulfur dioxide (SO_2). The stack is 35.0 meters high and has an inside diameter of 1.56 meters. The stack gas velocity is 13.2 meters per second, and stack gas temperature is 394 K. The tallest existing building is 12 meters high. The stack is located on the west side of the building, adjacent to it.

Meteorology of the Area

The average annual ambient air temperature is 18.3 °C, and the average annual mixing height is 1200 meters. The wind rose for Tulsa airport is shown in Figure 6-4. Approximately 45.5% of the year, the wind blows from four directions: north, north-northeast, south, and south-southeast.

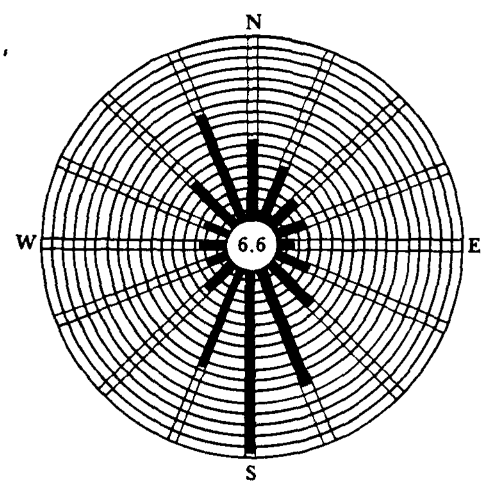


Figure 6-4. Tulsa wind rose.

New Proposed Construction

A new stack will be built that will be 35.0 meters high, will have an inside diameter of 1.56 meters, and will emit 1.5 grams per second (52 tons per year) of SO_2. It will be built next to a building that is 16 meters high. The stack gas velocity will be 13.2 meters per second, and gas temperature will be 394 K. The new construction will be 20 meters east of the existing stack (Figure 6-5).

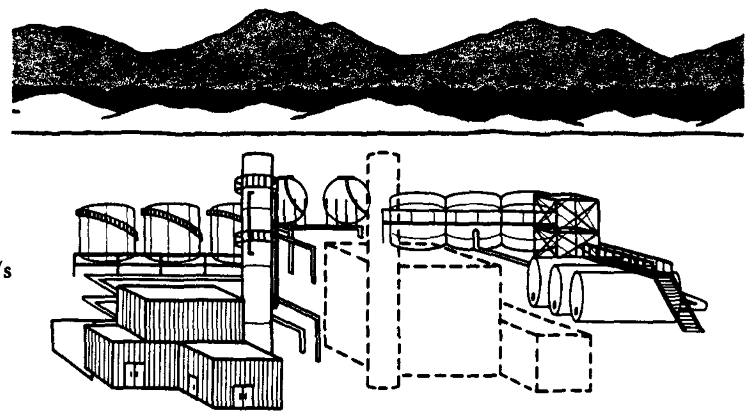


Figure 6-5. Proposed construction.

Model Selection and Application

The UNAMAP package has a wide range of regulatory models available. The choice of models was narrowed to point source dispersion models available on UNAMAP since these are point sources. The *Guideline on Air Quality Models* recommends that the modeler screen a site before committing to an expensive, refined model. It was decided to use the PTPLU screening model in conjunction with the conservative time-scaling factors in EPA's *Volume 10 Guideline* to model the impact of the oil refinery. These factors assume that the maximum 3-hour and 24-hour values are 90% and 40% of the maximum 1-hour value, respectively. A conservative scaling factor for annual average concentrations is 10% of the 1-hour maximum.

Since existing emissions exceed 100 tons per year of SO_2, this is already a major source. The new stack will add 52 tons per year of SO_2 to the atmosphere, which is a significant increase under EPA PSD regulations. Thus, the new stack at the oil refinery must be modeled to ensure it does not violate the Class II PSD increments for SO_2 of 20 $\mu g/m^3$ (annual average), 91 $\mu g/m^3$ (24-hour maximum) and 512 $\mu g/m^3$ (3-hour maximum). No Class I lands exist within 50 km of the refinery. The stack parameters and emission rates for the new stack were entered into the PTPLU model along with values for temperature and mixing height at the site. The modeling results are shown in Figure 6-6 for 1-hour SO_2 concentrations. The maximum 1-hour value is 8.7 $\mu g/m^3$ and occurs at a distance of 442 m from the stack. Using EPA scaling factors, conservative estimates of SO_2 concentrations for longer averaging times are obtained, and these are shown in Table 6-1. The results indicate the new stack will not violate the Class II PSD increments for SO_2.

Table 6-1. Maximum SO_2 concentrations from the new stack.

Averaging time	Maximum impact ($\mu g/m^3$)	Class II PSD increment ($\mu g/m^3$)
3-hour	8	512
24-hour	3	91
Annual	1	20

Under New Source Review, the refinery must also demonstrate that it will not exceed the NAAQS for SO_2, given the new emissions source. To do this, both stacks at the refinery were modeled with the PTPLU screening model used in conjunction with the conservative scaling factors. Since the height, temperature, velocity, and diameter of the new stack are the same as the parameters for the old stack, the emissions were combined and modeled as one source (Figure 6-7). The maximum 1-hour SO_2 concentration for the entire plant is 28 $\mu g/m^3$ and is scaled to appropriate averaging times in Table 6-2. The results indicate no problems with the NAAQS either.

The EPA PTPLU screening model has been used to make conservative estimates of air quality impacts. Since the oil refinery can demonstrate compliance with the PSD increments and the NAAQS using PTPLU, there is no need to run a more expensive, refined model.

Table 6-2. Maximum SO_2 concentrations from both stacks.

Averaging time	Maximum impact ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)
3-hour	25	1300
24-hour	11	365
Annual	3	80

PTPLU (VERSION 81036)
AN AIR QUALITY DISPERSION MODEL IN
SECTION 3 MODELS PROPOSED SEP80 FOR 81 GUIDELINES.
IN UNAMAP (VERSION 4) DEC 80
SOURCE FILE 13 ON UNAMAP MAGNETIC TAPE FROM NTIS.
NEW STACK AT THE OIL REFINERY

>>>INPUT PARAMETERS<<<

SOURCE		***OPTIONS***	***METEOROLOGY***	
EMISSION RATE =	1 50 (G/SEC)	IF = 1, USE OPTION	AMBIENT AIR TEMPERATURE =	291 00 (K)
STACK HEIGHT =	35 00 (M)	IF = 0, IGNORE OPTION	ANEMOMETER HEIGHT =	10 00 (M)
STACK DIAM =	1 56 (M)	IOPT(1) = 0 (GRAD PLUME RISE)	MIXING HEIGHT =	1200.00 (M)
EXIT VELOCITY =	13 20 (M/SEC)	IOPT(2) = 0 (STACK DOWNWASH)	WIND PROFILE EXPONENTS =	A: .10, B: .15, C: 20
STK GAS TEMP =	394 00 (K)	IOPT(3) = 0 (BUOY INDUCED DISP.)		D: .25, E: .30, F: 30
			RECEPTOR HEIGHT =	0 0 (M)

>>>CALCULATED PARAMETERS<<<

VOLUMETRIC FLOW = 25 23 (M**3/SEC) BUOYANCY FLUX PARAMETER = 20 59 (M**4/SEC**3)

ANALYSIS OF CONCENTRATION AS A FUNCTION OF STABILITY AND WIND SPEED

****EXTRAPOLATED WINDS****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)
1	0 50	6 4485E-06	0 916	449 1(2)	0 57	6 6954E-06	0 868	400.4(2)
1	0 80	7 3538E-06	0 750	293 8(2)	0 91	7 5777E-06	0.712	263 4(2)
1	1 00	7 7437E-06	0 684	242 1(2)	1 13	7 9420E-06	0 651	217 7(2)
1	1 50	8 3106E-06	0 584	173 0	1 70	8 4335E-06	0 557	156 8
1	2 00	8 5461E-06	0 526	138 5	2 27	8 5952E-06	0 495	126 3
1	2 50	8 6622E-06	0 475	117 8	2 83	8 7101E-06	0 452	108 1
1	3 00	8 7172E-06	0 442	104 0	3 40	8 6989E-06	0 422	95 9

****EXTRAPOLATED WINDS****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)
2	0 50	3 0371E-06	2 769	449 1(2)	0 60	3 4335E-06	2 366	378 2(2)
2	0 80	4 0874E-06	1 880	293 8(2)	0 97	4 5545E-06	1 618	249 5(2)
2	1 00	4 6441E-06	1 574	242 1(2)	1 21	5 1284E-06	1 361	206 6(2)
2	1 50	5 6891E-06	1 158	173 0	1 81	6 1550E-06	1 012	149 4
2	2 00	6 3886E-06	0 945	138 5	2 41	6 7897E-06	0 834	120 8
2	2 50	6 8579E-06	0 817	117 8	3 02	7 1754E-06	0 726	103 6
2	3 00	7 1672E-06	0 729	104 0	3 62	7 3963E-06	0 653	92.2
2	4 00	7 4755E-06	0 618	86 8	4 83	7 5373E-06	0 560	77 9
2	5 00	7 5357E-06	0 549	76 4	6 03	7 4565E-06	0 503	69 3

****EXTRAPOLATED WINDS****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)
3	2 00	5 4443E-06	1 677	138 5	2 57	6 0782E-06	1 375	115 6
3	2 50	6 0127E-06	1 405	117 8	3 21	6 5595E-06	1 167	99 5
3	3 00	6 4232E-06	1 225	104 0	3 85	6 8661E-06	1 029	88 7
3	4 00	6 9171E-06	1 004	86 8	5 14	7 1457E-06	0 859	75 3
3	5 00	7 1310E-06	0 874	76 4	6 42	7 1665E-06	0 761	67.2
3	7 00	7 1275E-06	0 728	64 6	8 99	6 8710E-06	0 647	58 0
3	10 00	6 7038E-06	0 619	55 7	12 85	6 1967E-06	0 564	51 1
3	12 00	6 3485E-06	0 577	52 3	15.42	5 7526E-06	0 531	48 4
3	15 00	5 8224E-06	0 535	48 8	19 27	5 1585E-06	0 499	45 7

****EXTRAPOLATED WINDS****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)
4	0 50	5 4618E-07	35 381	449 1(2)	0 68	8 3902E-07	22 072	337 8(2)
4	0 80	1 0246E-06	17 263	293 8(2)	1 09	1 4993E-06	10 641	224 2(2)
4	1 00	1 3476E-06	12 201	242 1(2)	1 37	1 9035E-06	8 078	186 4
4	1 50	2 0864E-06	7 139	173 0	2 05	2 7774E-06	4 778	135 9
4	2 00	2 7177E-06	4 937	138 5	2 74	3 4720E-06	3 393	110 7
4	2 50	3 2520E-06	3 766	117 8	3 42	3 9842E-06	2 758	95 6
4	3 00	3 6963E-06	3 060	104 0	4 10	4 3423E-06	2 317	85 5
4	4 00	4 2952E-06	2 369	86 8	5 47	4 7835E-06	1 803	72 8
4	5 00	4 6652E-06	1 943	76 4	6 84	4 9850E-06	1 520	65 3
4	7 00	4 9979E-06	1 495	64 6	9 57	5 0174E-06	1 218	56 6
4	10 00	4 9977E-06	1 187	55 7	13 68	4 7119E-06	1 007	50 1
4	12 00	4 8602E-06	1 075	52 3	16 41	4 4257E-06	1 000	47 6
4	15 00	4 5807E-06	1 000	48 8	20 52	3 9776E-06	0 955	45 1
4	20 00	4 0306E-06	0 962	45 4	27 36	3 3716E-06	0 889	42 6

****EXTRAPOLATED WINDS****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)
5	2 00	4 0281E-06	5 749	99 5	2 91	3 4485E-06	4 909	91 9
5	2 50	3 6776E-06	5 227	94 9	3 64	3 1299E-06	4 483	87 8
5	3 00	3 4051E-06	4 847	91 4	4 37	2 8838E-06	4 169	84 7
5	4 00	3 0012E-06	4 318	86 2	5 82	2 5132E-06	4 000	80 2
5	5 00	2 7096E-06	4 000	82 5	7 28	2 2359E-06	3 748	76 9

****EXTRAPOLATED WINDS****

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)
6	2 00	3 1294E-06	11 953	88 5	2 91	2 7108E-06	9 971	82 2
6	2 50	2 8777E-06	10 722	84 7	3 64	2 4756E-06	9 011	78 8
6	3 00	2 6790E-06	9 832	81 8	4 37	2 2915E-06	8 319	76 3
6	4 00	2 3796E-06	8 633	77 5	5 82	2 0169E-06	7 338	72 5
6	5 00	2 1602E-06	7 839	74 4	7 28	1 8160E-06	7 000	69 8

(1) THE DISTANCE TO THE POINT OF MAXIMUM CONCENTRATION IS SO GREAT THAT THE SAME STABILITY IS NOT LIKELY TO PERSIST LONG ENOUGH FOR THE PLUME TO TRAVEL THIS FAR

(2) THE PLUME IS OF SUFFICIENT HEIGHT THAT EXTREME CAUTION SHOULD BE USED IN INTERPRETING THIS COMPUTATION AS THIS STABILITY TYPE MAY NOT EXIST TO THIS HEIGHT ALSO WIND SPEED VARIATIONS WITH HEIGHT MAY EXERT A DOMINATING INFLUENCE

(3) NO COMPUTATION WAS ATTEMPTED FOR THIS HEIGHT AS THE POINT OF MAXIMUM CONCENTRATION IS GREATER THAN 100 KILOMETERS FROM THE SOURCE

Figure 6-6. PTPLU model run for the new stack at the oil refinery.

BOTH STACKS AT THE OIL REFINERY

>>>INPUT PARAMETERS<<<

SOURCE
EMISSION RATE = 4 78 (G/SEC)
STACK HEIGHT = 35 00 (M)
STACK DIAM = 1 56 (M)
EXIT VELOCITY = 13 20 (M/SEC)
STK GAS TEMP = 394 00 (K)

OPTIONS
IF = 1. USE OPTION
IF = 0. IGNORE OPTION
IOPT(1) = 0 (GRAD PLUME RISE)
IOPT(2) = 0 (STACK DOWNWASH)
IOPT(3) = 0 (BUOY INDUCED DISP)

METEOROLOGY
AMBIENT AIR TEMPERATURE = 291 00 (K)
ANEMOMETER HEIGHT = 10 00 (M)
MIXING HEIGHT = 1200 00 (M)
WIND PROFILE EXPONENTS = A 10. B 15. C 20
D 25. E 30. F 30
RECEPTOR HEIGHT = 0 0 (M)

>>>CALCULATED PARAMETERS<<<

VOLUMETRIC FLOW = 25 23 (M**3/SEC)
BUOYANCY FLUX PARAMETER = 20.59 (M**4/SEC**3)

ANALYSIS OF CONCENTRATION AS A FUNCTION OF STABILITY AND WIND SPEED

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)	****EXTRAPOLATED WINDS**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)
1	0 50	2 0549E-05	0 916	449 1(2)	0 57	2 1336E-05	0 868	400.4(2)
1	0 80	2 3434E-05	0 750	293 8(2)	0 91	2 4148E-05	0 712	263 4(2)
1	1 00	2 4676E-05	0 684	242 1(2)	1 13	2 5308E-05	0 651	217.7(2)
1	1 50	2 6483E-05	0 584	173 0	1 70	2 6875E-05	0 557	156 8
1	2 00	2 7234E-05	0 526	138 5	2 27	2 7390E-05	0 495	126 3
1	2 50	2 7603E-05	0 475	117 8	2 83	2 7756E-05	0 452	108.1
1	3 00	2 7779E-05	0 442	104 0	3 40	2 7721E-05	0 422	95.9

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)	****EXTRAPOLATED WINDS**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)
2	0 50	9 6782E-06	2 769	449 1(2)	0 60	1 0942E-05	2 366	378 2(2)
2	0 80	1 3025E-05	1 880	293 8(2)	0 97	1 4514E-05	1 618	249 5(2)
2	1 00	1 4799E-05	1 574	242 1(2)	1 21	1 6343E-05	1 361	206.6(2)
2	1 50	1 8129E-05	1 158	173 0	1 81	1 9614E-05	1 012	149 4
2	2 00	2 0358E-05	0 945	138 5	2 41	2 1637E-05	0 834	120 8
2	2 50	2 1854E-05	0 817	117 8	3 02	2 2866E-05	0 726	103 6
2	3 00	2 2840E-05	0 729	104 0	3 62	2 3570E-05	0 653	92 2
2	4 00	2 3822E-05	0 618	86 8	4 83	2 4019E-05	0 560	77 9
2	5 00	2 4014E-05	0 549	76 4	6 03	2 3761E-05	0 503	69 3

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)	****EXTRAPOLATED WINDS**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)
3	2 00	1 7349E-05	1 677	138 5	2 57	1 9369E-05	1 375	115 6
3	2 50	1 9161E-05	1 405	117 8	3 21	2 0903E-05	1 167	99.5
3	3 00	2 0469E-05	1 225	104 0	3 85	2 1880E-05	1 029	88 7
3	4 00	2 2042E-05	1 004	86 8	5 14	2 2771E-05	0 859	75 3
3	5 00	2 2724E-05	0 874	76 4	6 42	2 2837E-05	0 761	67.2
3	7 00	2 2713E 05	0 728	64 6	8 99	2 1895E-05	0 647	58.0
3	10 00	2 1363E-05	0 619	55 7	12 85	1 9747E-05	0 564	51 1
3	12 00	2 0231E 05	0 577	52 3	15 42	1 8332E-05	0 531	48 4
3	15 00	1 8554E-05	0 535	48 8	19 27	1 6438E-05	0 499	45 7

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)	****EXTRAPOLATED WINDS**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)
4	0 50	1 7405E-06	35 381	449 1(2)	0 68	2 6737E-06	22 072	337 8(2)
4	0 80	3 2650E-06	17 263	293 8(2)	1 09	4 7777E-06	10 641	224 2(2)
4	1 00	4 2943E-06	12 201	242 1(2)	1 37	6 0658E-06	8 078	186 4
4	1 50	6 6487E-06	7 139	173 0	2 05	8 8505E-06	4 778	135.9
4	2 00	8 6604E-06	4 937	138 5	2 74	1 1064E-05	3 393	110 7
4	2 50	1 0363E-05	3 766	117 8	3 42	1 2696E-05	2 758	95.6
4	3 00	1 1779E-05	3 060	104 0	4 10	1 3837E-05	2 317	85 5
4	4 00	1 3687E-05	2 369	86 8	5 47	1 5244E-05	1 803	72 8
4	5 00	1 4866E-05	1 943	76 4	6 84	1 5886E-05	1 520	65.3
4	7 00	1 5927E-05	1 495	64 6	9 57	1 5989E-05	1 218	56 6
4	10 00	1 5926E-05	1 187	55 7	13 68	1 5015E-05	1 007	50 1
4	12 00	1 5488E-05	1 075	52 3	16 41	1 4103E-05	1 000	47 6
4	15 00	1 4597E-05	1 000	48 8	20 52	1 2675E-05	0 955	45 1
4	20 00	1 2844E-05	0 962	45 4	27 36	1 0744E-05	0 889	42 6

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)	****EXTRAPOLATED WINDS**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)
5	2 00	1 2836E-05	5 749	99 5	2 91	1 0989E-05	4 909	91 9
5	2 50	1 1719E-05	5 227	94 9	3 64	9 9739E-06	4 483	87 8
5	3 00	1 0851E-05	4 847	91 4	4 37	9 1897E-06	4 169	84 7
5	4 00	9 5637E-06	4 318	86 2	5 82	8 0089E-06	4 000	80 2
5	5 00	8 6346E-06	4 000	82 5	7 28	7 1250E-06	3 748	76 9

STABILITY	WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)	****EXTRAPOLATED WINDS**** WIND SPEED (M/SEC)	MAX CONC (G/CU M)	DIST OF MAX (KM)	EFFECT HT (M)
6	2 00	9 9724E-06	11 953	88 5	2 91	8 6385E-06	9 971	82 2
6	2 50	9 1702E-06	10 722	84 7	3 64	7 8889E-06	9 011	78 8
6	3 00	8 5371E-06	9 832	81 8	4 37	7 3023E-06	8 319	76 3
6	4 00	7 5829E-06	8 633	77 5	5 82	6 4271E-06	7 338	72 5
6	5 00	6 8837E-06	7 839	74 4	7 28	5 7869E-06	7 000	69 8

(1) THE DISTANCE TO THE POINT OF MAXIMUM CONCENTRATION IS SO GREAT THAT THE SAME STABILITY IS NOT LIKELY TO PERSIST LONG ENOUGH FOR THE PLUME TO TRAVEL THIS FAR

(2) THE PLUME IS OF SUFFICIENT HEIGHT THAT EXTREME CAUTION SHOULD BE USED IN INTERPRETING THIS COMPUTATION AS THIS STABILITY TYPE MAY NOT EXIST TO THIS HEIGHT ALSO WIND SPEED VARIATIONS WITH HEIGHT MAY EXERT A DOMINATING INFLUENCE

(3) NO COMPUTATION WAS ATTEMPTED FOR THIS HEIGHT AS THE POINT OF MAXIMUM CONCENTRATION IS GREATER THAN 100 KILOMETERS FROM THE SOURCE

Figure 6-7. PLPLU model run for both stacks at the oil refinery.

Review Exercise

1. The terrain that surrounds the oil refinery in terms of the stacks can be described as a. flat. b. complex. c. mountainous. d. indeterminate. e. land-to-sea interface.	
2. The oil refinery plans to a. build a new office building. b. build a new stack. c. build three new stacks. d. renovate the existing stack. e. renovate a barbeque pit.	1. a. flat.
3. The air quality model chosen to estimate ground-level concentrations around the refinery was a. DIFKIN. b. CDM. c. CRSTER. d. APRAC-IA. e. PTPLU.	2. b. build a new stack.
4. The reason for first screening the oil refinery, rather than using a refined model analysis, was that a. the oil refinery did not wish to obtain an accurate answer. b. the *Guideline on Air Quality Models* allows screening first. c. refined models are not available. d. the oil refinery president tossed a coin. e. screening provides a more precise analysis than a refined model.	3. e. PTPLU.
5. The maximum 24-hour SO_2 concentration from the new stack at the refinery was a. 87 $\mu g/m^3$. b. 9 $\mu g/m^3$. c. 1 $\mu g/m^3$. d. 3 $\mu g/m^3$. e. 91 $\mu g/m^3$.	4. b. the *Guideline on Air Quality Models* allows screening first.
	5. d. 3 $\mu g/m^3$.

Lesson 2
Iron-casting Plant

Lesson Goal and Objectives

Goal

To familiarize you with an actual case of air quality modeling of an iron-casting plant and interpreting the results of that modeling.

Objectives

Upon completing this lesson, you should be able to:

1. describe the terrain features around the iron-casting plant.
2. describe the new proposed construction.
3. name the air quality model chosen.
4. explain why the company used a refined model analysis.
5. identify the results of the modeling analysis.

Introduction

The second case study to be examined is an iron company in northeast Michigan. It has been at its present location for 40 years. Renovations have taken place over the years, but no projects to build or change the facilities are planned. However, if modeling demonstrates that the plant is responsible for high total suspended particulate (TSP) concentrations downwind, then additional air pollution control equipment will be required. The State of Michigan requested an air quality demonstration to determine the impact of emissions on the urban area where violations of the TSP National Ambient Air Quality Standards (NAAQS) have been measured.

Description of Area

The northeastern section of Michigan can be described as having gently rolling terrain with elevations not exceeding 6 meters surrounding the plant. An urban area is located mostly to the south and west of the plant. The urban area has a population of approximately 125,000. The area around the urban center is forested farm land. A major river runs south to north by the western edge of the company.

Description of the Plant Site

The company is located next to the river in a flat area. The area within 5 kilometers is essentially flat. Two casting plants are located about 1 kilometer apart along the river (Figure 6-8). The buildings are not taller than 24 meters. The grey iron-casting plant is approximately 305 meters long and 305 meters wide. The nodular iron-casting plant is 30 meters long and 245 meters wide. A typical iron-melting furnace is shown in Figure 6-9. The plant has 14 stacks (see Table 6-3) for the source inventory). The company built nine of the stacks to 70 meters to minimize ground-level concentrations. These are termed *tall stacks*. Air pollution controls were installed on the five smaller (24 to 51 meter) stacks to minimize the ground-level concentrations.

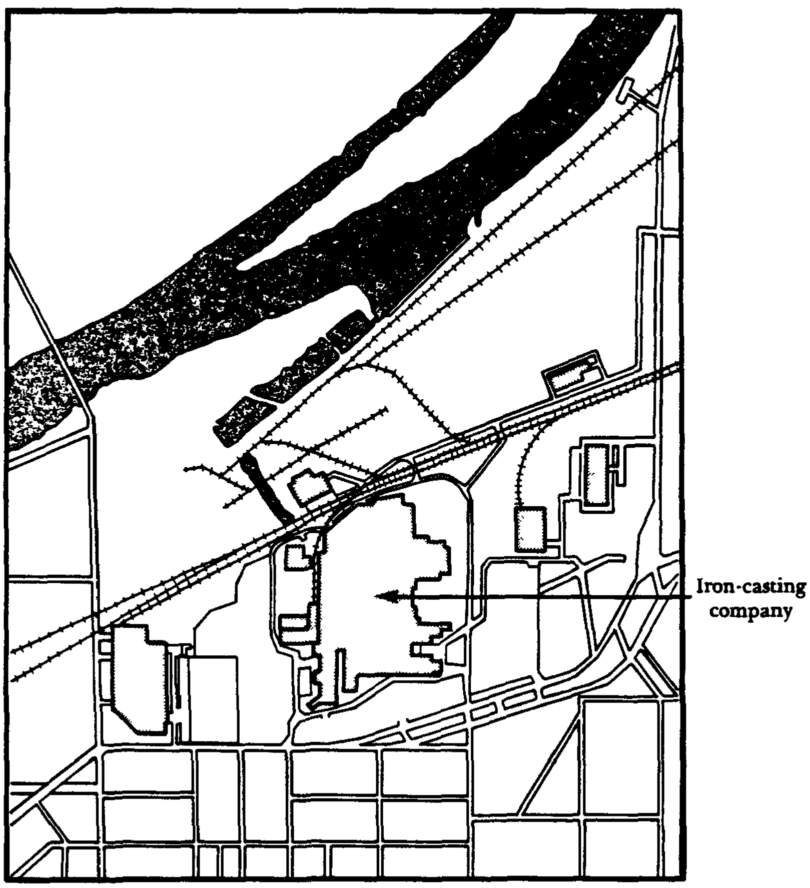


Figure 6-8. Iron-casting company.

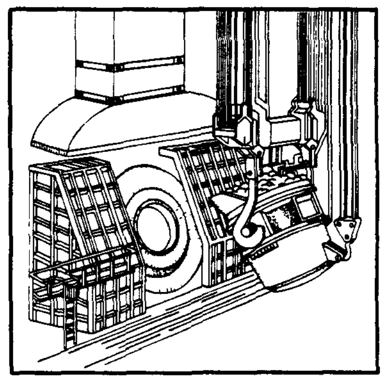


Figure 6-9. Iron-melting furnace.

Table 6-3. Iron-casting plant emissions inventory.

Source identification	E coordinate (m)	M coordinate (m)	Particulate emission rate (g/s)	Stack height (m)	Temperature (K)	Inner diameter at top (m)	Exit velocity (m/s)
G.I.C.P.							
Cupola A-1	263866	4814693	3245.76	70.104	316.3	1.524	22.76
Cupola B-2	263852	4814717	158	51.21	321.89	1.37	17.34
Cupola C-3	263853	4814725	158	51.21	321.89	1.37	17.34
Cupola D-4	263877	4814743	3245.76	70.104	316.3	1.524	7.85
Cupola E-5	263866	4814750	158	70.104	316.3	1.524	17.34
Cupola G-6	263856	4814782	3965.98	70.104	316.3	1.524	24.1
Cupola K-7	263893	4814868	158	51.21	321.89	1.37	18.53
Cupola L-8	263911	4814929	0	24.38	505.2	2@2.03 × 12.8(a)	0.54
Cupola H-9	263911	4814929	100	24.38	505.2	2@2.03 × 12.8(a)	0.54
N.I.C.P.							
Cupola 1	264549	4815695	2419.2	70.104	310.78	0.91	15.78
Cupola 2	264572	4815695	2419.2	70.104	310.78	0.91	15.78
Cupola 3	264597	4815695	2419.2	70.104	310.78	0.91	15.78
Cupola 4	264623	4815695	2419.2	70.104	310.78	0.91	15.78
Cupola 5	264665	4815695	394.1	70.104	310.78	1.524	19.7

Meteorology of the Area

Michigan is influenced by cold, dry arctic air masses in the winter and warm, moist Gulf of Mexico air masses in the summer. A tremendous amount of influence is exerted on the area by Lake Michigan, Lake Superior, and Lake Huron. The lakes store vast amounts of heat. They release heat and moisture into arctic air as the air passes over them. The resulting convection causes large amounts of precipitation (snow in winter and rain in the summer) to fall. The winter winds are predominantly from the northwest, turning southwesterly after the passage of a storm system. The summer winds are generally southerly.

The company obtained a computerized tape of hourly meteorological data recorded at the airport closest to the plant. Since the terrain is flat, the winds, temperatures, atmospheric stability, and mixing heights are similar at both locations. The meteorological data were preprocessed.

Model Selection and Application

The objective of this modeling analysis was to determine the contribution of the iron company's emissions to high TSP levels measured on the adjacent urban area. A screening model was not used first in this case because of the large number of very different sources of particulate emissions. The PTPLU model, which estimates the maximum concentration under various meteorological conditions for a single point source, was inappropriate for a situation with 14 different stacks, each having a maximum impact at a different location downwind. Because of the uncertainty over where the combined maximum impact might be, a refined model was used with a closely spaced grid receptor network. The recommended multiple point source model for urban areas is RAM. The RAM model was used in this case with a receptor grid measuring 3.3 km wide by 3.9 km long, containing receptor points spaced only 300 km apart (Figure 6-10). A year of preprocessed meteorological data and the emissions inventory shown in Table 6-3 were used as inputs for the model.

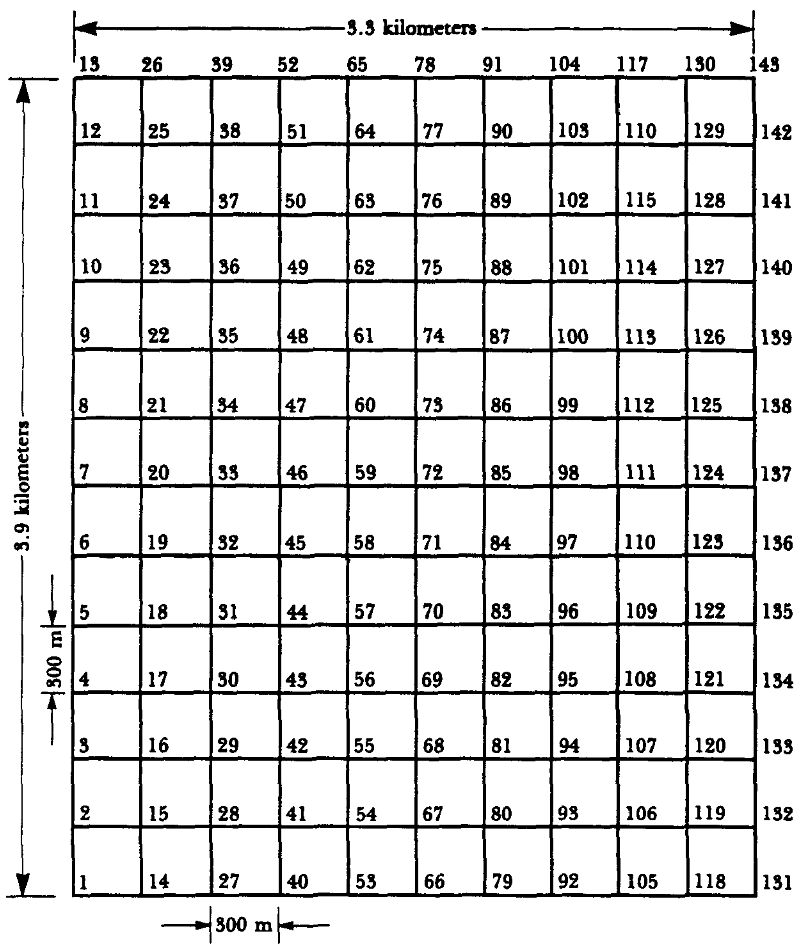


Figure 6-10. Receptor grid used in the RAM model.

The modeling results shown in Figure 6-11 give the five highest 24-hour TSP concentrations at each of the receptor sites. The highest, second-highest concentration is the largest value in the second column of results in Figure 6-11, namely 352 $\mu g/m^3$ at receptor number 73, which is 300 m due north of the company. Since the 24-hour NAAQS for TSP (secondary standard) is 150 $\mu g/m^3$ (see Unit 2/Lesson 1), the impact from the casting plants alone is sufficient to violate the NAAQS for TSP in the nearby urban area. Based on these modeling results, the iron company subsequently negotiated a TSP control strategy with the State of Michigan that involved retrofit application of control technology.

FIVE HIGHEST 24-HOUR CONCENTRATIONS (JULIAN DAY MAX OCCURS)
(MICROGRAMS/M**3)

RECEPTOR NO.	1	2	...	5	MEAN CONCENTRATION
1	28.94(133.)	22.02(154.)		18.20(109.)	1.42
2	56.50(154.)	42.74(129.)		23.71(232.)	2.02
3	59.25(192.)	41.44(107.)		23.43(146.)	2.48
4	41.47(192.)	24.58(107.)		19.39(106.)	2.43
5	86.72(147.)	50.94(221.)		30.00(161.)	2.60
6	52.53(147.)	50.35(84.)		34.72(258.)	2.67
7	62.62(134.)	44.00(62.)		25.64(151.)	2.20
8	40.89(134.)	35.55(203.)		19.40(258.)	1.83
9	23.09(203.)	21.94(174.)		17.97(62.)	1.49
10	16.74(250.)	15.66(286.)		12.31(179.)	1.15
⋮					
72	184.74(348.)	158.43(236.)		142.10(248.)	30.15
73	415.55(215.)	351.57(217.)		293.21(200.)	55.80
74	184.39(205.)	103.52(294.)		81.82(272.)	17.40
75	32.00(205.)	50.29(210.)		46.23(214.)	8.61
76	36.27(210.)	34.70(175.)		33.71(214.)	5.48
77	30.84(145.)	30.57(347.)		26.87(181.)	3.89

Figure 6-11. RAM model output.

Review Exercise

1. The terrain surrounding the iron-casting plant can be described as a. complex. b. hilly. c. orographic. d. flat. e. rolling.	
2. The iron company plans to a. renovate all facilities. b. build new stacks. c. tear down the tallest stacks. d. paint the buildings. e. possibly add air pollution control equipment.	1. d. flat.
3. A refined model was chosen to estimate air pollution impact around the iron company because a. screening techniques are considered childish. b. it has a large number of different emission sources. c. iron-casting plants may not run screening models. d. the State of Michigan prefers refined techniques in all permit cases. e. the iron company does not have a screening model.	2. e. possibly add air pollution control equipment.
4. What was the highest, second-highest 24-hour TSP concentration in this case study? a. 150 $\mu g/m^3$ b. 352 $\mu g/m^3$ c. 80 $\mu g/m^3$ d. 400 $\mu g/m^3$ e. 1200 $\mu g/m^3$	3. b. it has a large number of different emission sources.
5. Which air quality model was chosen for the iron-casting plant? a. RAM urban b. RAM rural c. CRSTER d. PTPLU e. VALLEY	4. b. 352 $\mu g/m^3$
	5. a. RAM urban

Unit 7
Summary

Slide/Tape Presentation

Cassette no. 3 and keyed slides 3-1 through 3-18.

Unit Goal and Objectives

Goal

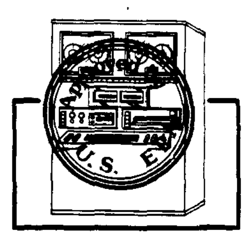
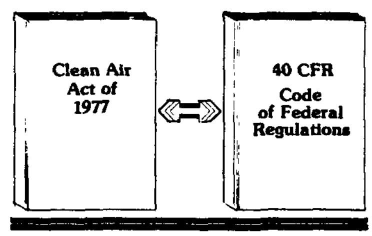
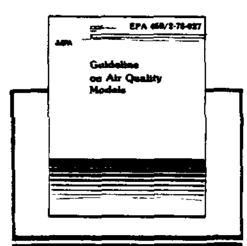
To review the major topics about Gaussian point source modeling covered in this course.

Objectives

Upon completing this unit, you should be able to:

1. name the two legal documents that require air quality modeling.
2. list the three air quality programs that require air quality modeling.
3. list the three basic types of input data to air quality models.
4. classify the Gaussian plume model.
5. identify the name of the computerized tape package that makes the air quality models available.
6. identify the screening models discussed that are available on the computerized tape package.
7. identify the refined models discussed that are available on the computerized tape package.
8. identify the reason for discussing case studies.

Air Quality Modeling
Summary

Slide no.	Script	Selected visuals*
1.	Title slide—no narrative	**Air Quality Modeling Summary**
2.	In this course we've looked at dispersion modeling in detail. Here, we will summarize the major points developed throughout this course. Air quality models such as the Gaussian plume point dispersion models are used not only to identify and evaluate existing industrial and urban air pollution problems, but also to predict future problems, and, therefore, to help avoid them.	**Gaussian Plume Point Source Dispersion Models**
3.	The U.S. Environmental Protection Agency has approved Gaussian plume point dispersion models for use in regulatory applications.	
4.	Congress initially passed the Clean Air Act in 1970. It was subsequently amended in 1977. The amendments required EPA to conduct a conference on air quality modeling, and they required the promulgation of regulations that specified air quality models applicable to the Prevention of Significant Deterioration program.	
5.	The Clean Air Act and the *Code of Federal Regulations* by themselves do not specify when air quality models will be required, or how they will be used. To recommend **specific** air quality models, the *Guideline on Air Quality Models* was published in April, 1978.	

*Illustrations included here, no live shots included.

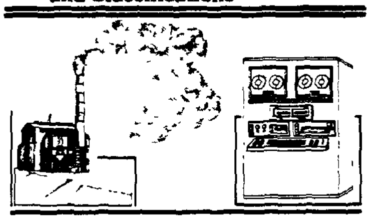
Slide no.	Script	Selected visuals

6. Three programs evolved from the regulations that require the application of models in specific cases where the air quality may be in question: Prevention of Significant Deterioration, New Source Review, and Control Strategy Evaluation. The PSD program was established to limit the deterioration in ambient air quality beyond that existing on a specific baseline date. A permit review process uses modeling to evaluate whether or not potential emissions from a **new source** will cause or contribute to a violation of the National Ambient Air Quality Standards, or exceed the PSD increments. And, modeling can identify and evaluate the control strategy required to solve industrial and urban air pollution problems.

- **Prevention of Significant Deterioration**
- **New Source Review**
- **Control Strategy Evaluations**

7. An air quality model can be **characterized** and **classified** so that a modeler can choose the proper one for each specific situation.

Characteristics and Classifications



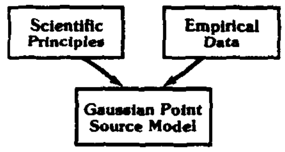
8. Three basic types of data are input into air quality models: source factors, site factors, and meteorological factors. Source factors are related to the location and characteristics of pollutant emission sources. Site factors represent the effects of terrain on dispersion and the location of sensitive receptors. Meteorological factors include all of the parameters that define transport and dispersion of pollutant mass, such as wind speed, wind direction, stability class, and mixing height.

Basic Model Inputs

- Source Factors
- Site Factors
- Meteorological Factors

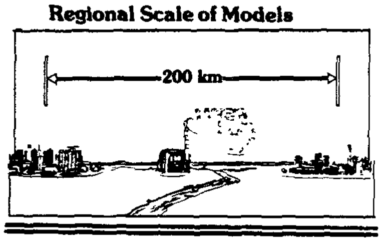
9. Air quality models can be classified as being empirical, semi-empirical, or numerical. The Gaussian point source models we have discussed in this course are semi-empirical. That is, they are derived from scientific principles, such as conservation of mass, but they also rely on empirically defined parameters, such as the dispersion rates sigma y and sigma z.

Semi-empirical Models



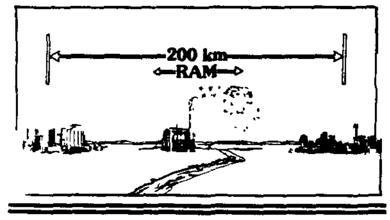
10. Each model is also designed for a specific distance scale, such as the Regional Scale. For instance, the distance between two cities affected by a source may be 200 kilometers.

Regional Scale of Models

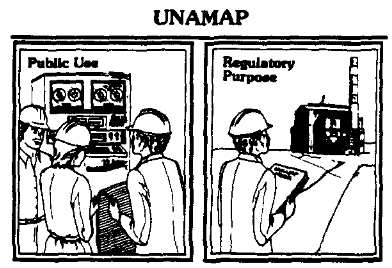


Slide no. **Script** **Selected visuals**

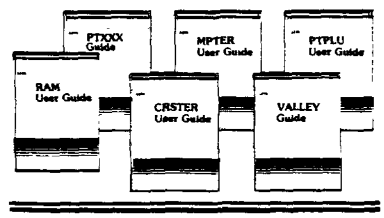
11. An air quality model such as RAM may cover only a smaller distance, namely 50 kilometers. Therefore, another model should be chosen to interpret data from this situation.



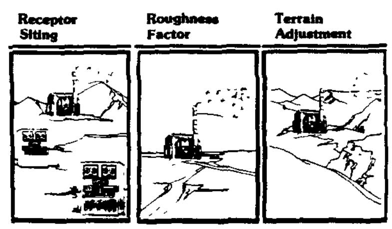
12. Gaussian dispersion models are available on EPA's UNAMAP Series, the User's Network of Applied Models of Air Pollution. These models, available for public use, are updated periodically. They are also used as a base for many current regulatory procedures.



13. Some of the Gaussian plume point source models currently available on UNAMAP are used for screening. These include the PTXXX series, PTPLU, and VALLEY. Screening eliminates, with little effort, sources that clearly will not cause or contribute to a violation of the ambient air standards. Screening models require only limited input data and make a number of "worst-case" assumptions. However, some models use more refined techniques, such as CRSTER, MPTER, and RAM. Refined models require more data than screening models. They use actual meteorological episodes, and actual source positions and characteristics to assess potential air quality violations.



14. Special adjustments can also be added to the models that make them more useful. These include receptor siting, roughness factors, and terrain adjustments. A model will be run differently depending on the adjustment made.



15. Two case studies were examined in some detail in this course. The cases, an oil refinery and an iron-casting plant, demonstrated practical applications of air quality modeling.

16. In summary, we rely on air quality models to relate the release of air pollutants from sources to the corresponding concentrations of pollutants in the ambient air. These data can help predict the changes in air quality for either the present or for future years.

Slide no.	Script	Selected visuals
17. Credit: Crew		**Air Quality Modeling Summary** Technical Content: Peter Guldberg, Don Bullard Design: Marilyn Peterson Illustrations: Kathy Ward Photography/Audio: David Churchill Narration: Rick Palmer
18. Credit: EPA/NET Contract		Lecture development and production by: Northrop Services Inc. under EPA Contract No. 68-02-3573
19. Credit: NET		Northrop Environmental Training

Review Exercise

1. The two documents that require air quality modeling by law are the a. Constitution and Bill of Rights. b. Magna Carta and 14th Amendment to the Constitution. c. Clean Air Act Amendments of 1977 and the *Code of Federal Regulations*. d. States Rights and 17th Amendment to the Constitution.	
2. List the three air quality programs that require air quality modeling.	1. c. Clean Air Act Amendments of 1977 and the *Code of Federal Regulations*.
3. The Gaussian plume model is a(n) ________ model.	2. New Source Review, Prevention of Significant Deterioration, and Control Strategy Evaluation
4. List the three basic types of input data to air quality models.	3. semi-empirical
5. The name of the computerized tape package that contains the air quality models is a. ASCII. b. UNAMAP. c. EBCDIC. d. none of the above	4. source factors, site factors, and meteorological factors
6. The computer tape package contains screening models. The ones discussed in this course are a. CDM, PTDIS, PTMAX, PTMTP, VALLEY. b. CRSTER, PTDIS, PTMAX, PTMTP, PTPLU. c. PTMAX, PTDIS, PTMTP, PTPLU, VALLEY. d. PTMAX, PTDIS, PTMTP, PTPLU, PAL.	5. b. UNAMAP.
7. The computer tape package contains refined models. The ones discussed in this course are a. CRSTER, MPTER, RAM. b. CRSTER, MPTER, RAM, ISC. c. CDM, MPTER, VALLEY. d. CRSTER, CDM, RAM, MPTER.	6. c. PTMAX, PTDIS, PTMTP, PTPLU, VALLEY.
8. True or False? The reason for discussing case studies in detail is that it demonstrates practical applications of air quality models.	7. a. CRSTER, MPTER, RAM.
	8. True

TECHNICAL REPORT DATA

(Please read Instructions on the reverse before completing)

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4. TITLE AND SUBTITLE APTI Course SI:410 Introduction to Dispersion Modeling		5. REPORT DATE March, 1983 6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S) Peter Guldberg, Donald R. Bullard, Marilyn Peterson		8. PERFORMING ORGANIZATION REPORT NO.
9. PERFORMING ORGANIZATION NAME AND ADDRESS Northrop Services, Inc. P.O. Box 12313 Research Triangle Park, NC 27709		10. PROGRAM ELEMENT NO. B18A2C 11. CONTRACT/GRANT NO. 68-02-2374
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15. SUPPLEMENTARY NOTES

EPA Project Officer for this Student Guidebook is R. E. Townsend, EPA-ERC, MC 20, Research Triangle Park, NC 27711

16. ABSTRACT

The Student Guidebook is to be used in taking APTI Course SI:410, "Introduction to Dispersion Modeling." This Guidebook directs the students progress through the course material. This Guidebook will assist the student in learning about dispersion modeling.

This Guidebook is intended for use in conjunction with slide/tape presentations and other readings. The only required reading is the Guideline on Air Quality Models, EPA 450/2-78-027.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Air Quality Modeling Self-instructional Guidebook Dispersion	Self-instructional Guidebook	13B 5I 68A

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