Carbon Monoxide State Implementation Plan

APPENDIX C
MODELING DOCUMENTATION

Las Vegas Valley Non-attainment Area

Clark County, Nevada

August 2000

Department of Comprehensive Planning

Clark County Board of Commissioners

APPENDIX C

MODELING
DOCUMENTATION

Section	**Title**
One	Modeling Protocol for the Las Vegas Valley Carbon Monoxide Urban Airshed Model Update Project.
Two	The Las Vegas Valley Carbon Monoxide Urban Airshed Model Update Project – Phase II Field Data Collection.
Three	The Las Vegas Valley Carbon Monoxide Urban Airshed Model Update Project – Phase II UAM Base Case and Sensitivity Applications (*phase2-base*).
Four	The Las Vegas Valley Carbon Monoxide Urban Airshed Model Update Project – Phase II Modeling to Demonstrate Attainment of the Carbon Monoxide Standard (*phase2-final*).
Five	Micro-scale Hot Spot Modeling with CAL3QHC in Las Vegas.
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APPENDIX C

Section One
Modeling Protocol for the Las Vegas Valley Carbon Monoxide Urban Airshed Model Update Project

Final Protocol

MODELING PROTOCOL FOR THE LAS VEGAS VALLEY CARBON MONOXIDE URBAN AIRSHED MODEL UPDATE PROJECT

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1 INTRODUCTION

BACKGROUND

Two National Air Quality Standards (NAAQS) have been established for carbon monoxide (CO); a one-hour standard of 35 ppm, and an eight-hour standard of 9 ppm. Regions that violate either of these standards more than three times in a three year period are classified as nonattainment areas. Although CO concentrations in the Las Vegas Valley (LVV) have never exceeded the one-hour standard, they have historically exceeded the eight hour standard during the late fall/winter season. During these months, development of surface-based inversions at night leads to stagnation conditions that trap pollutants in the valley and concentrates them near the ground. Almost all CO emanates from near-ground sources, the majority resulting from motor vehicle emissions. The buildup of CO causes exceedance violations of the eight-hour NAAQS, historically in a limited area surrounding the East Charleston monitoring station. This site is near the intersection of three major transportation corridors (the "Five Points" highway intersection), and is located within a topographic depression where valley air often converges during stagnation events.

There has been a declining trend over the past 15 years in the number of LVV exceedance events as well as the intensity of CO concentrations. Between December 1988 and December 1991, numerous exceedances were recorded, all at the East Charleston site, with the highest 8-hour CO concentration being 14.4 ppm in December 1988. This same site also recorded ten exceedances during the 1991/92 winter season alone (November 1991 through February 1992). During the 1994/95 winter season, the LVV experienced eight unhealthy days for CO (above 100 PSI or 8.7 ppb), all of which were recorded at the East Charleston monitoring station. On three of these unhealthy days, CO concentrations exceeded the NAAQS. Nearly identical trends occurred during the 1995/96 winter season, in which four days exceeded the NAAQS.

The number and severity of the CO violations in the past have prompted the U.S. Environmental Protection Agency (U.S. EPA) to designate the LVV as a moderate CO nonattainment area. The 1990 Clean Air Act Amendments (CAA) mandate that moderate nonattainment areas implement emission control measures such that the CO NAAQS are attained by December 31, 1995; to demonstrate attainment, an implementation plan must have been prepared and submitted to EPA by November 15, 1992.

In 1992, Clark County developed CO Urban Airshed Model (UAM) capabilities for the LVV to facilitate the preparation of a moderate area Carbon Monoxide Air Quality Implementation Plan (CO AQIP.). The episode day modeled was the night of December 7-8, 1990. On-road motor vehicle emissions were estimated by the TRFCONV model using a 1990 loaded roadway network generated by the Regional Transportation Commission (RTC) travel demand model (TRANPLAN). The U.S. EPA's MOBILE 4.1 emission factor model was utilized to generate emission factors for various speeds and temperatures. Stationary, area and off-road mobile source emissions were preprocessed by the Emissions Preprocessing System (EPS) to the temporal and spatial resolution required by the UAM. The performance of the UAM was assessed in accordance with the U.S. EPA recommendations, and deemed acceptable based upon statistical measures that were within recommended ranges. It was clear, however, that the limited quantity of available meteorological data affected the model's ability to accurately portray the buildup and transport of CO. The UAM was then utilized in the evaluation of emission control measures for the CO Air Quality Implementation Plan (AQIP) NAAQS 1995 attainment demonstration.

In 1995, the sensitivity of UAM base case performance was investigated by updating the mobile source inventory using MOBILE 5A. While emissions were increased, overall model performance was not markedly improved. The attainment demonstration was revisited as well using a new modeling approach which utilized data obtained from the Clark County Carbon Monoxide Hotspot Study. The new approach was an emissions rollback modeling technique dubbed the "wedding cake model", which used proportional emissions based on the tracer gas experiment from the hotspot study. This model was developed cooperatively by the Clark County Health District APCD and U.S. EPA Region IX.

During the summer of 1996, the U.S. EPA proposed to grant a one year extension of Clark County's moderate nonattainment date to December 31, 1996. At its discretion, EPA may grant an extension if the area has: (1) measured no more than one exceedance of the CO NAAQS at any monitoring site in the nonattainment area in the year preceding the extension year, and (2) complied with the requirements and commitments pertaining to the applicable implementation plan for the area. EPA may grant up to two one-year extensions if these conditions have been met. According to EPA, "the intended effect of extending the attainment date is to allow Nevada and Clark County either to fully implement and strengthen current CO control measures, or to adopt additional control measures prior to the 1996-97 winter CO season in an effort to attain the CO NAAQS." At the end of the extension year, EPA will review the area's air quality data to determine if the area has attained the CO NAAQS. If a sufficient demonstration cannot be made that the area has met the extension criteria, and EPA determines that the area has not demonstrated attainment of the CO NAAQS, then the area will be reclassified as serious.

STUDY OBJECTIVES

In response to continuing exceedances of the 8-hour CO NAAQS, Clark County has initiated the Las Vegas Valley Carbon Monoxide Urban Airshed Model Update Project intended to build off of previous UAM CO modeling for the LVV and support preparation of a new AQIP. Major attention will be given to improving estimates of emission rates and their spatial/temporal distributions, and utilizing improved air quality and meteorological monitoring networks for CO episodes in 1995 and 1996. A special task is included to investigate certain improvements to the UAM that may better treat the circumstances unique to environments conducive to CO episodes.

The following specific objectives of this study are to be met in two study phases:

1 Develop 1995 baseline emissions inventories from the latest traffic, roadway network, and mobile emission factor models and data available, and from the latest survey data on area and point sources;

2. Evaluate UAM performance for a winter 1995/96 episode using 1995 emissions estimates and CO air quality and meteorological input data from the expanded Clark County Health District monitoring network; identify data gaps and weaknesses that could be remedied by special study field monitoring, and investigate potential improvements to UAM so that the model is better adapted to treat highly stagnant and stable atmospheric conditions;

3. Develop inputs and apply the CAL3QHC microscale intersection model for "hotspot" modeling of the "Five Points" intersection;

4. Based upon findings in (2), conduct a special field monitoring program during the 1996/97 winter season that enhances the existing air quality and meteorological network's ability to properly characterize three dimensional CO and meteorological patterns at high time resolution;

5. Develop 1996 emissions and UAM input fields, apply the model for a 1996/97 CO episode identified from (4), and evaluate model performance;

6. Apply UAM and CAL3QHC for the years 2000, 2005, 2010, and 2020 using projected emission estimates that incorporate the effects of projected growth as well as mandated and alternative control measures to assist in the development of a new CO AQIP;

7. Transfer the technology and knowledge necessary for Clark County to use the UAM as an effective planning tool.

The U.S. EPA requires that the agency responsible for AQIP development first submit a modeling protocol for review and approval. The modeling protocol document serves several purposes: (1) it serves as a mechanism to fully scope, develop and document all procedures, assumptions, and technical decisions relating to the modeling and the arguments and analyses upon which they are based; (2) it supplies a means for public comment among interested parties; and (3) it supplies a means for EPA review and approval of the modeling project.

This document represents the modeling protocol for the current UAM update project. It describes in detail the procedures to be followed in all facets of UAM CO modeling, from assistance in episode selection and development of conceptual models, through data preparation, wind modeling/UAM preprocessing, emissions development, and model performance evaluation. In the case that EPA approval is not initially granted, discussions will be held with the County's Project Oversight Committee and EPA regarding the issues, and all necessary revisions to the protocol will be made for resubmission to EPA. Subsequently, during project execution, any departures from the protocol that will be essential to address unexpected problems and technically improve the modeling system or analyses of model predictions will be noted via memoranda submitted to the Project Oversight Committee and EPA for review.

PROJECT OVERVIEW

The UAM, the Diagnostic Wind Model (DWM), and the CAL3QHC intersection model will serve as the backbone of the current CO modeling system. Model performance will be evaluated using both statistical and graphical methods, as well as through a "process-oriented" approach that compares model predictions with conceptual models of conditions associated with elevated CO concentrations in the LVV. The UAM is the EPA-recommended model for regulatory CO air quality attainment demonstrations. The DWM is the minimum meteorological model recommended by EPA to supply wind fields to the UAM (note that it cannot supply other important parameters such as diffusion break height and vertical temperature lapse rates), and has been used in the past for CO modeling in the LVV. A Gaussian line source/intersection model (CAL3QHC) will be used to supplement UAM for subgrid-scale estimates of road side impacts from highway emissions (i.e., CO hotspots).

Depending on the quality and quantity of available meteorological data, and upon the resulting performance of the DWM, the Pennsylvania State University/National Center for Atmospheric Research prognostic Meteorological Model (MM5) may be employed in some facility to investigate the degree to which gridded meteorological fields are improved. The prognostic MM5 has been widely used to address transport and turbulent exchange issues on scales ranging from the regional through micro scale, employing its nested-grid architecture and four dimensional data assimilation (4DDA) option. The MM5 represents a vast improvement over DWM in terms of technical rigor and mass/energy conservation, while also properly simulating full three dimensional wind, temperature, and turbulence fields. Despite these advantages, however, it is not at all clear that MM5 can generate markedly improved gridded meteorological fields under stagnant atmospheric conditions, particularly if the results are dominated by the 4DDA component (in such circumstances, MM5 then becomes a technically rigorous form of a diagnostic model). If it is decided that MM5 analyses are to be undertaken, comparisons between inputs generated by the DWM and MM5 will be made to identify whether or not the prognostic model is any more capable of treating the stagnation and highly stable conditions representative of high CO in the Las Vegas Valley, and whether UAM predictions of CO distributions are improved.

While diagnostic wind modeling may have contributed to poor UAM CO performance in the past, this problem may be alleviated in the current project through the use of the expanded APCD monitoring network and the incorporation of special field study data. Still, the design of certain UAM components is insufficient to properly treat conditions associated with stagnant CO episodes (e.g., the necessity to specify diffusion break height, and use of hour-mean wind fields). Past model performance problems are therefore likely to have been a result of the limitations in the UAM-IV itself, which are responsible for a level of uncertainty that may equal or exceed uncertainties associated with input meteorological fields.

Technically speaking, advanced models such as UAM version V (UAM-V), SAQM, or the new Extended Urban/Regional Airshed Model (UAMX) would be superior to UAM for CO predictions. However, use of any model but UAM could present risk or difficulties in obtaining EPA acceptance, since UAM is the regulatory model. Given the current controversy surrounding use of UAM-V for ozone SIPs, it seems unlikely EPA would be receptive to use of non-guidance models for CO modeling. Instead, we plan to use UAMX as an experimental test bed to investigate potential UAM model improvements. In this manner we can inexpensively evaluate the value of UAM modifications without the expense of modifying UAM first and ultimately finding little or no improvement to the predicted CO distributions. An investigation will be undertaken to determine if certain UAMX processes and treatments that markedly improve CO performance could be incorporated into the UAM and tested (see Task 2.6 for a description of potential improvements). Documentation of the changes that we feel are useful, including justification and a full technical description, will be compiled and submitted to the Project Oversight Committee and to the EPA for review.

Organization

Clark County has established a Project Oversight Committee to recommend technical approaches to all phases of the modeling study. The committee sets the objectives of the study, establishes a schedule and implements any necessary project modifications as the study proceeds. Further, the committee will promote technical credibility in order to provide consensus building among interested parties concerning modeling issues and assumptions, and to provide documentation for technical decisions made in applying the model as well as the procedures followed in reaching these decisions. Table 1-1 lists the members of the Project Oversight Committee and indicates those who are also members of the Air Quality Planning Committee responsible for AQIP development. The roles of each member of the Project Oversight Committee as set forth by Clark County are listed below:

Actively participate as a member of the oversight committee;
Assist in the selection of design day/episode;
Determine the adequacy of ambient air quality data;
Review/comment on the modeling protocol;
Participate and implement any necessary modifications to the project as deemed necessary by the committee to assure adherence to the project schedule;
Provide input concerning the technical specifications of the emissions inventory;
Promote technical credibility to the modeling;
Develop and recommend emission control strategies;
Review and comment on final documentation;
Recommend technical approaches for all phases of the modeling project;
Provide documentation for assumptions made in updating the model, including the procedures followed related to technical decisions;
Review and provide written recommendations on errors or deficiencies provided by the consultant of existing UAM files;
Review and provide written comments/recommendations on diagnostic steps associated with the initial simulations;
Provide input regarding training needs and attend scheduled training sessions;
Review and provide written comment on documentation for Phase I;
Attend monthly meeting (following Air Quality Planning Committee meetings) or more frequently as necessary.

Table 1-1. Project Oversight Committee Members

Name/Title	Affiliation
William Cates, Principal Planner	Clark County Department of Comprehensive Planning
Clete Kus, Principal Planner	Clark County Department of Comprehensive Planning
Jeff Jensen, Modeler	Clark County Department of Comprehensive Planning
Michael Naylor, Director	Air Pollution Control Division Clark County Health District
Femi Durosinmi	Air Pollution Control Division Clark County Health District
Teresa Arnold, Airport Land Use/Environmental Planner	McCarran International Airport Department of Aviation
Leslie Long, Environmental Engineer	City of North Las Vegas Department of Public Works
Susan Gray, Community Planner	City of Henderson Planning Department
Patricia Manry, Transportation Analyst II	Nevada Department of Transportation Planning Division
Dennis Mewshaw, Senior Planner	Regional Transportation Commission of Clark County
John Sullard, Community Development Director	City of Boulder City
Dr. David James, Assistant Professor UNLV	Transportation Research Center Department of Civil and Environmental Engineering
Lori Wohletz, Administrative/Environmental Officer	City of Las Vegas Department of Public Works
Scott Bohning	U.S. EPA
Interested Party: Jerry Horn	Chevron

As contractors to the Las Vegas Valley Carbon Monoxide Urban Airshed Model Update Project, the staffs of ENVIRON International Corp. (ENVIRON), Desert Research Institute (DRI), and Sonoma Technology, Inc. (STI) will be undertaking the tasks set forth in this protocol. An organization chart displaying key personnel and their roles in the Project by phase is shown in Figure 1-1.

Technical Approach

The study objectives will be met through the completion of several tasks under two project phases. In Phase I, all necessary UAM and CAL3QHC inputs will be developed for a winter 1995/96 base case CO episode. A review of UAM performance with special regard to data gaps, uncertainties, and limitations, will shape the implementation of a special field monitoring program under Phase II during the 1996/97 winter season. A new modeling episode will be selected from this period, and the routine and special field data collected will be used for new UAM and CAL3QHC modeling. Finally, impacts from several future year emissions estimates will be modeled in Phase II. A list of specific tasks by Phase is listed below, along with a brief description of activities to be performed. The procedures to be followed in executing these tasks are described in more detail in the following sections.

Phase I

Task 1 Develop a Modeling Protocol (this document): Develop a protocol to describe in detail the procedures to be followed in all facets of UAM CO modeling. To be submitted to the U.S. EPA Region IX for review and approval.

Task 2 Database Issues

- Task 2.1 Baseline Emissions Inventory: Calculate the 1995 annual and seasonal CO emissions inventories for on-road mobile, area, and point sources.
- Task 2.2 Episode Selection: Compile and evaluate all available meteorological and CO air quality data from the winters between 1994-96 to identify a CO episode for Phase I modeling.
- Task 2.3 Prepare Meteorological/Air Quality Files: Develop DWM meteorological and air quality files in UAM format for each episode day.
- Task 2.4 Review Existing UAM Input Files: Review and evaluate the methodology used to develop UAM input files that currently exist for the December 7-8 1990 episode, and examine the files for errors/omissions, accuracy, and representativeness of the Las Vegas Valley for the given conditions.
- Task 2.5 Prepare Episode Day Emission Inventory: Develop the episode day gridded emissions inventory from the 1995 base year inventory developed under Task 2.1.
- Task 2.6 Data Quality Assurance and Model Diagnostic Analysis: Review all UAM input emissions, meteorological, and initial/boundary fields prior to all UAM simulations. Perform diagnostic sensitivity tests to understand UAM response to changes in various parameters and input files known to be the most influential on CO predictions. Evaluate UAM performance in predicting CO throughout the Las Vegas modeling domain using statistical, graphical, and process-oriented methods. Assess the adequacy of the existing monitoring network to ensure that a reasonable degree of confidence may be placed on the resulting statistics. Investigate potential improvements to both meteorological fields (including the possible use of MM5) and to UAM itself that better characterize the stagnation conditions associated with high CO events in the LVV.

Task 3 CAL3QHC Microscale Modeling: Review CAL3QHC modeling procedures, update the input data required by the model, and operate the model for at least the "Five Points" intersection.

Task 4 Transfer and Installation of Data Files and Source Code at Clark County: Transfer all input and output data and source code for all programs used in the completion of the project via a medium decided upon by ENVIRON and Clark County.

Task 5 UAM Training: Conduct two, two-day training sessions at Clark County and/or UNLV.

Task 6 Project Reporting and Documentation: Prepare monthly progress reports, present status reports on current activities to the Project Oversight Committee and the Air Quality Planning Committee, prepare a report for the Regional Transportation Commission Executive Advisory Committee after the completion of the on-road mobile source inventory and episode day emissions inventory, and document all Phase I activities in a draft and final Phase I report.

Phase II

Task 1 Design Field Data Collection Protocol for the 1996 Winter Season: In consultation with the Project Oversight Committee, a monitoring plan will be developed that will: (1) provide a list of required equipment; (2) outline procedures for data collection, processing, validating, and reporting (including recommended quality assurance procedures for generating data with known accuracy, precision, and validity); (3) give the locations, time, and frequency for data collection; and (4) suggest the recommended time-period for the winter study. The required deployment of equipment and their locations will be determined during Phase II-Task 1 using results of the model evaluation in Phase I

Task 2 Deploy Equipment, Collect Data, and Process the Data: Conduct the field study following the design developed in Phase II-Task I.

Task 3 Prepare Meteorological and Air Quality Input Data: Combine data from the extra sites deployed in the intensive field study with data collected by Clark County Health District APCD for use in a model application for one or more winter 1996/97 CO episodes. Work under Phase II-Task 3 will progress similarly to the approach discussed under Task 2.3 of Phase I.

Task 4 Prepare Episode Day Emission Inventory: Develop the 1996 episode day emissions inventory from the 1995 base year inventory developed under Phase 1-Task 2.1.

Task 5 Data Quality Assurance and Model Diagnostic Analysis: Perform a full data quality assurance procedure and model diagnostic analysis for the CO modeling episode(s) selected from the 1996-97 intensive monitoring study. All tests and analyses described in Task 2.6 under Phase I will be performed for the new episode(s), including an assessment of all potential model improvements described therein.

Task 6 Develop Future Year UAM Files: Develop UAM-formatted future year emission, initial condition and boundary files for 2000, 2005, 2010 and 2020 from the 1995 base year files developed under Phase 1-Task 2.1. Run UAM with these inputs to analyze effectiveness of various control strategies in meeting the CO NAAQS.

Task 7 Transfer of Data Files to Clark County: Transfer data files and modeling source code as described in Phase I-Task 4.

Task 8 Project Reporting and Documentation: Prepare Phase II monthly progress reports and presentations, draft and final reports as described in Phase I-Task 6.

Emissions, Air Quality and Meteorological Databases

LVV emissions data will be obtained primarily from two County agencies. For on-road mobile emissions, the Regional Transportation Commission (RTC) of Clark County will provide 1995 link location and traffic volume. Emission factor parameters will be obtained from the Clark County Department of Comprehensive Planning and the Clark County Health District Air Pollution Control Division (APCD). The APCD will also supply 1995 annual emission estimates for area sources. The data will be examined for accuracy and completeness and supplemented with EPA data if needed. For point sources, 1995 annual emissions will be obtained from the APCD based on their permitting database.

Ambient LVV surface CO air quality and meteorological data (wind speed/direction, temperature, humidity, and pressure) are routinely logged by a network of monitoring stations operated by the APCD. This agency is also responsible for performing quality assurance checks on the data, and updating and maintaining a publicly-accessible database. Table 1-2 presents a list of APCD monitoring stations denoting the types of data recorded, coordinates, and probe heights.

Further, routine surface hourly meteorological data is available from the National Weather Service for Nellis Air Force Base and McCarran International Airport. These reports are typically instantaneous observations taken 0-10 minutes before each hour, and therefore do not provide information on conditions at these two sites over an entire hour. The only routine upper air meteorological data available for the area is from the Desert Rock Airport rawinsonde site located about 100 km northwest of downtown Las Vegas. This site is operated by the National Weather Service and supplies tropospheric temperature and wind soundings every 12 hours.

During December 1994, Desert Research Institute conducted a tracer experiment to investigate transport patterns during conditions of high stagnation and CO buildup. The existing APCD network was augmented with several more meteorological sites as well as tethersonde measurements to obtain shallow vertical soundings of temperature and wind. This database is currently available from DRI, and may be used in the current study for Phase I modeling of an episode in winter 1995/96 (see Section 2). For Phase II, the standard APCD monitoring network will be again augmented during winter 1996/97, including the addition of potentially many more CO samplers, several more surface monitoring sites and two Doppler acoustic sounders (sodars). These data will be compiled and archived by Sonoma Technology, Incorporated (STI) for use in Phase II modeling. The data will be collected, analyzed, and compiled into a separate database to be maintained by DRI and Sonoma Technology Incorporated.

ENVIRON will utilize as much of the available data from APCD, NWS, DRI, and STI as possible in development of UAM input fields. All data necessary to develop initial/boundary, wind, temperature, diffusion break (mixing height) and meteorological scalars files will be maintained on ENVIRON's computer system. Delivery of raw data, as well as completed UAM input and output files, will be made to Clark County at the end of each project phase.

Deliverables, Reporting and Documentation

The following items will be delivered to the Clark County Department of Comprehensive Planning and to members of the Project Oversight Committee and the Air Quality Planning Committee:

Phase I

- A modeling protocol (this document) describing the tasks to be undertaken during the LVV CO UAM Update Project;
- A summary of the 1995 annual and seasonal CO emissions inventories for on-road mobile sources at the completion of Task 2.1; this report will summarize the connection between network congestion and emissions distributions and strengths;
- A memorandum describing the results of an analysis of ambient CO data with recommendations on which CO episodes are the best modeling candidates (as part of Task 2.2);
- A memorandum documenting any suspected errors or deficiencies found in the existing December 7-8, 1990 modeling database, at the completion of Task 2.4;
- A summary of the episodic 1995 CO emissions inventories for all sources at the completion of Task 2.5;
- A memorandum documenting all UAM performance diagnostic steps performed as part of Task 2.6 including an assessment of the adequacy of the existing monitoring network in terms of the degree of confidence that may be placed on the resulting statistics; this memorandum will also note the impacts to model performance from modification of certain UAM components along with a full technical discussion and recommendations;
- A review of the modeling inputs for CAL3QHC along with recommendations for improvements as part of Task 3, and a summary of the hotspot modeling CO concentrations for each intersection modeled at the completion of this task;
- Transfer of all emissions, wind model, UAM, and CAL3QHC data files, as well as source code for all programs (including any modifications to UAM) used in the completion of Phase I, as part of Task 4;
- Monthly progress reports describing activities carried out over the previous month, submitted to Clark County by the 10th of every month; the project manager will travel to Las Vegas to present a monthly status report to the Project Oversight Committee;
- A draft Phase I report documenting all Phase I activities associated with meteorological and UAM-IV modeling, including results of sensitivity tests, model improvements, emissions summaries, model performance statistics, graphics, and conceptual model comparisons; comments on the Phase I draft from the various agencies will be delivered to ENVIRON for consideration in a Phase I final report after consultation with Clark County.

Table 1-2. Las Vegas Valley monitor information.

Site	Location (km)		Probe Height (m)		Measurement Data		
	UTM East	UTM North	Wind	CO	Temperature	Wind	CO
East Charleston (EC)	670.1	4003.0	6		✔	✔	✔
Proximity (PX)	670.1	4003.0			✔	✔	✔
Microscale	669.9	4003.0		4.0			✔
East Bonanza (CC)	667.4	4004.8	10		✔	✔	
City Center	667.7	4004.6		3.5	✔	✔	✔
East Sahara/Maycliff (MC)	672.2	4001.4	6.5	3.5	✔	✔	✔
Winterwood (WW)	675.0	4001.4	10		✔	✔	✔
Powerline (PL)	681.2	3988.0	6	3.5	✔	✔	✔
Craig Road (BS)	671.4	4012.7	10	3.5	✔	✔	✔
East Flamingo (FL)	666.0	3998.0	5.8	3.5	✔	✔	✔
Shadow Lane (SL)	665.3	4003.5	7.5	6.5	✔	✔	✔
E. Vegas Valley/Dime III (DM)	675.4	4000.7	7		✔	✔	
McDaniel P.O., NLV (LM)	668.7	4007.1	10	7	✔	✔	
McDaniel, LV	668.8	4007.2			✔	✔	
Paul Meyer (PM)	657.2	3997.1	10		✔	✔	✔
Pittman (PT)	680.4	3991.6	10	4.5	✔	✔	✔
West Alta/Walter Johnson (WJ)	656.4	4004.0	10		✔	✔	

Phase II

- A protocol for Phase II intensive monitoring that will provide procedures for data collection, processing, validating, and reporting including recommended quality assurance procedures for generating data with known accuracy, precision, and validity; the plan will cover: the data needed for modeling, the equipment required to collect the needed data, the locations, time, and frequency for data collection, and the recommended time-period for the winter study;
- A memorandum describing the results of an analysis of Phase II ambient CO data with recommendations on which CO episodes are the best modeling candidates;
- A summary of the episodic 1996 CO emissions inventories for all sources at the completion of Task 4;
- A memorandum documenting all UAM performance diagnostic steps performed as part of Task 5, along with a full technical discussion and recommendations;
- A summary of the episodic CO emissions inventories for the future years 2000, 2005, 2010, and 2020 at the completion of Task 6;
- Transfer of all Phase II field data and emissions, wind model, UAM, and CAL3QHC data files, as well as source code for all programs (including any modifications to UAM) used in the completion of Phase II, as part of Task 7;
- Monthly progress reports describing activities carried out over the previous month, submitted to Clark County by the 10th of every month; the project manager will travel to Las Vegas to present a monthly status report to the Project Oversight Committee;
- A draft Phase II report documenting all Phase II activities associated with the field monitoring study and meteorological/UAM-IV modeling including a summary of the new database, significant findings from the field study, emissions summaries, results of sensitivity tests and model improvements, model performance statistics, graphics, and conceptual model comparisons; comments on the Phase II draft from the various agencies will be delivered to the ENVIRON team for consideration in a Phase II final report after consultation with Clark County.

UAM Training

An objective of this project is the successful transfer of the technology and knowledge necessary for Clark County to use the UAM-IV as an effective planning tool. Meeting this objective requires providing effective training in four key areas:

Overview of the UAM structure and underlying assumptions to appreciate the strengths and limitations of the modeling approach.

Knowledge of available techniques for preparing UAM input databases (e.g., emissions and meteorology) to make the best use of the model and understand the strengths and limitations imposed by model inputs.

Familiarity with UAM input files and preprocessors to efficiently prepare and run different scenarios.

Familiarity with UAM postprocessing tools and output files to effectively visualize, comprehend and communicate results.

Training presentations will address all of these issues on levels accessible to both the Clark County modeling staff and the Project Oversight Committee. We will conduct two, two-day training sessions. Presentation materials will be reviewed by Clark County beforehand and any suggested modifications incorporated into the presentations.

ENVIRON currently runs UAM in-house on both of the computer platforms expected to be used by Clark County for LVV UAM applications (i.e., DEC Alpha with ULTRIX 4.4 and SGI with IRIX 5.3). Thus, UAM will be delivered to Clark County modeling staff ready to run on both platforms and we expect that installation will be straightforward and efficient. We are familiar with the compatibility issues that are raised by running UAM on both DEC and SGI platforms and can provide versions of UAM with code enhancements necessary for seamless operation on these two platforms (the issue being different binary representations on the two systems). We will ensure that the UAM is installed to the system administrator's and modeler's satisfaction prior to performing training.

As requested, an executuable version of DTIM2 will be supplied to the RTC and installed on a computer platform at their factility. Note that source code for DTIM2 is not publicly available.

Schedule

Figure 1-2 displays the schedule for both Phases of the LVV CO UAM Update Project. Phase I work began upon contractual approval by Clark County. Phase II authorization/vendor selection is stated in the RFP to be September 17, 1996. Therefore, we have used October 1, 1996 as the date that work under Phase II could begin. Historically, the highest CO concentrations occur during the winter season of November through February. Thus, it is imperative that planning for Phase II be begun as soon as possible prior to that date. Clearly, beginning planning for the field study in October for implementation in November is unrealistic. Based on comments offered by Clark County, we are hopeful that at least partial funding authorization for Phase II, allowing for earlier planning, can occur prior to October 1. We would work with Clark County under the Phase I effort funding to also assure maximum preparation for Phase II under Phase I.

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Figure 1-1. Project Organization.

1996/97

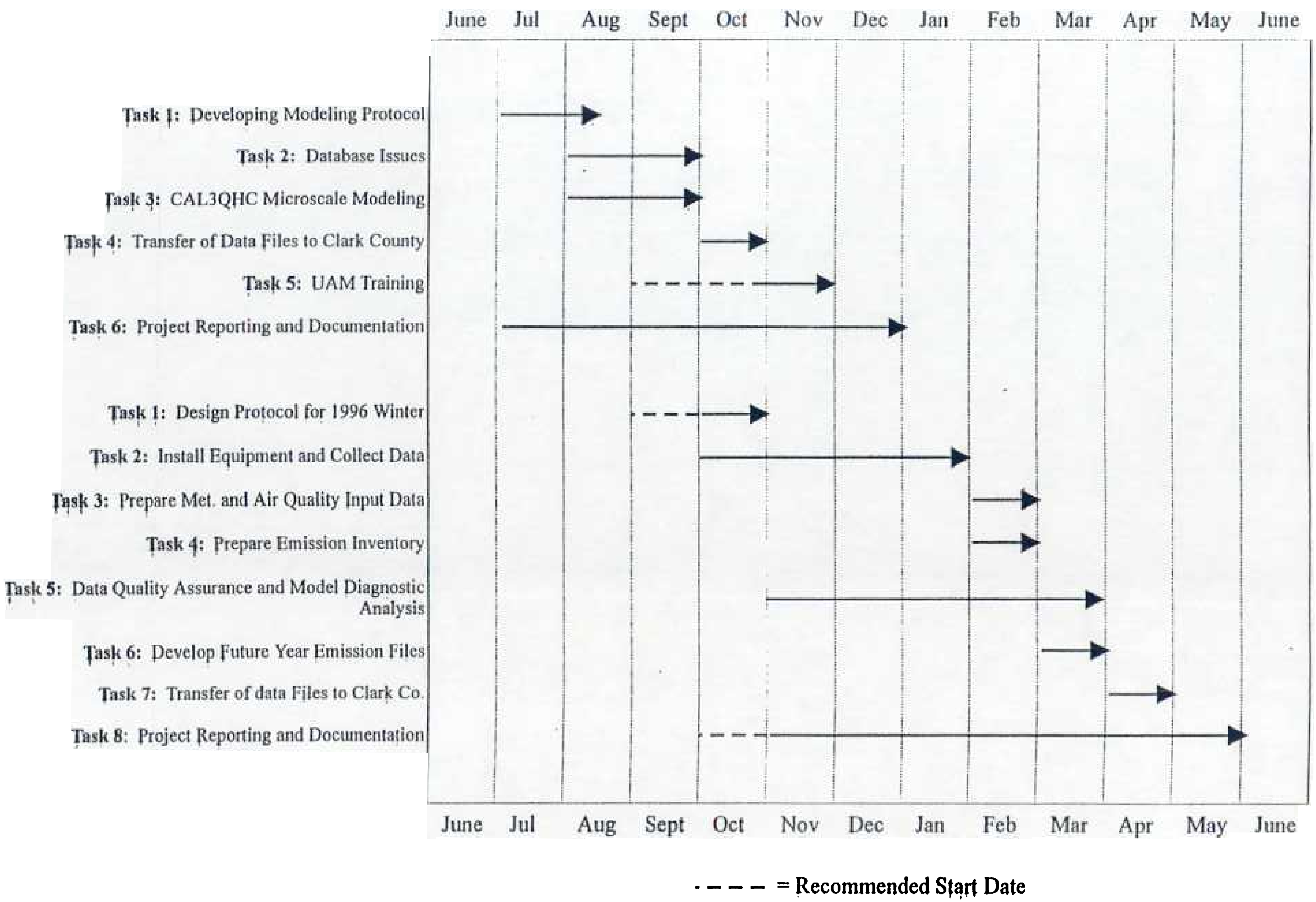

Figure 1-2. Timeline.

2. DEVELOPMENT OF PHASE I UAM BASE CASE INPUTS

This section of the modeling protocol presents the methodology to be followed in developing UAM input files, as well as specification of the modeling grid size/resolution and episode selection. In general, the procedures to be followed in developing the UAM inputs will be based upon the EPA guidance document for the regulatory application of UAM for area wide CO modeling (EPA, 1992). Deviations from this guidance are noted and rationalized.

MODELING GRID SPECIFICATION

The UAM and DWM grid structures will be based on the grids used in previous UAM modeling of the LVV for the December 7-8, 1990 episode. ENVIRON's review of this modeling raised the question as to whether the horizontal coverage of the UAM domain continues to encompass the City of Las Vegas, considering its rapid growth over the past six years and anticipated growth beyond the year 2000. In developing traffic data for mobile emission estimates, RTC staff have analyzed current Traffic Analysis Zone and land use databases, and utilized the extent of their spatial coverage as a surrogate for an "urban growth boundary". Assuming that the bulk of future urban growth will be contained within this boundary, it becomes evident that much of Las Vegas' growth will extend beyond the original UAM domain, particularly to the west and south. Discussions with the Project Oversight Committee yielded a consensus that the UAM domain should be expanded from a 40 by 40 grid to a 50 by 50 grid to entirely encompass the urban growth boundary. The only urbanized region that is not included in the grid is Boulder City, but this area is located outside the CO nonattainment basin. Emissions from that area should not have a significant impact on modeling results as drainage flow during CO episodes typically moves from the west/northwest to the southeast. Figure 2-1 displays the relationship between the CO nonattainment boundary and the original and current UAM modeling grids.

The UAM grid specifications for this study are as follows:

Origin in UTM zone 11:	642.000 km easting 3973.000 km northing
Number of columns:	50 (E-W) by 50 (N-S)
Number of layers:	5 (4 below diffusion break and above)
Cell size:	1 km
Minimum layer thickness:	20 m
Horizontal coverage:	2500 km^2
Vertical extent:	200 m

The previous modeling contractors stated that the use of four layers below the diffusion break height (depth of the inversion layer) is based upon evidence that the vertical CO concentration profile decreases rapidly within the surface-based inversion layer, and that at a minimum, four layers are needed to characterize this gradient (BRW and SAI, 1992). While this appears to be quite adequate, data from a 1994 intensive CO tracer field study will be analyzed to reaffirm this, and experiments with increased number of layers may be undertaken to investigate UAM sensitivity to this approximation. Similar experiments with finer horizontal resolution may also be performed.

In simulating wintertime CO conditions, stagnant conditions allow for drainage flows to dominate the near-surface wind fields. In the LVV, surrounding terrain features may influence the drainage flow that sets up along the axis of the various washes. Thus, wind modeling for the previous LVV UAM applications was performed on a grid that extends 20 km beyond the UAM grid in each direction to capture the potential influences of the significant terrain bordering the LVV. The DWM was designed to estimate mesoscale flow patterns and may generate unrealistically large slope-flows if terrain features are resolved at very small grid spacing. Acknowledging this drawback, the grid spacing for the DWM was set to 2 km rather than the 1 km used for the smaller UAM grid. The vertical extent was set to 200 m, divided into five layers each 40 m deep.

The DWM applications for the current study will utilize a similar meteorological grid structure as the previous study, with the exception that vertical resolution is doubled to 20 m. The minimum UAM layer thickness is 20 m, which occurs during most hours at night. Since the DWM layer thickness was 40 m in the previous study, the first four UAM layers mapped to only two DWM layers, so vertical wind profiles were not accurately depicted in UAM. The lack of vertical wind soundings exacerbated this problem. It is anticipated that the use of tethersonde soundings from special study data will allow for a finer DWM layer structure in the current project.

Figure 2-2 displays the horizontal coverage of the UAM and DWM grids in the LVV, with terrain contours and major traffic arteries overlaid. Figure 2-3 shows the UAM grid alone, with some major traffic routes and airports indicated.

EPISODE SELECTION

All available meteorological and CO air quality data from the winter 1994/95 CO season will be compiled and evaluated for Phase I modeling. The meteorological regime associated with high CO episodes in the Las Vegas Valley will be identified (in accordance with EPA guidance), and a conceptual model will be developed. Candidate CO episodes will be compiled and ranked according to peak observed CO concentration; the number of observation sites recording exceedances of the 8-hour CO NAAQS will also be tabulated. Meteorological conditions will also be evaluated, including an analysis reflecting the degree of stagnation from the local measurements, and an overview of synoptic or large-scale whether patterns. The resulting data will be submitted to the Project Oversight Committee with recommendations on which CO episodes are the best modeling candidates.

Recommendations will be based upon the quality and quantity of available data upon which a reliable conceptual model may be based; the degree to which observed meteorological patterns for a given CO episode match historical patterns associated with the stagnation regime, and expected difficulty in UAM modeling (if applicable) such that a process-oriented model evaluation will be credible. Following guidance procedures, the data must show that: (1) the episode does not appear to be the result of an exceptional event; (2) a complete routine data set

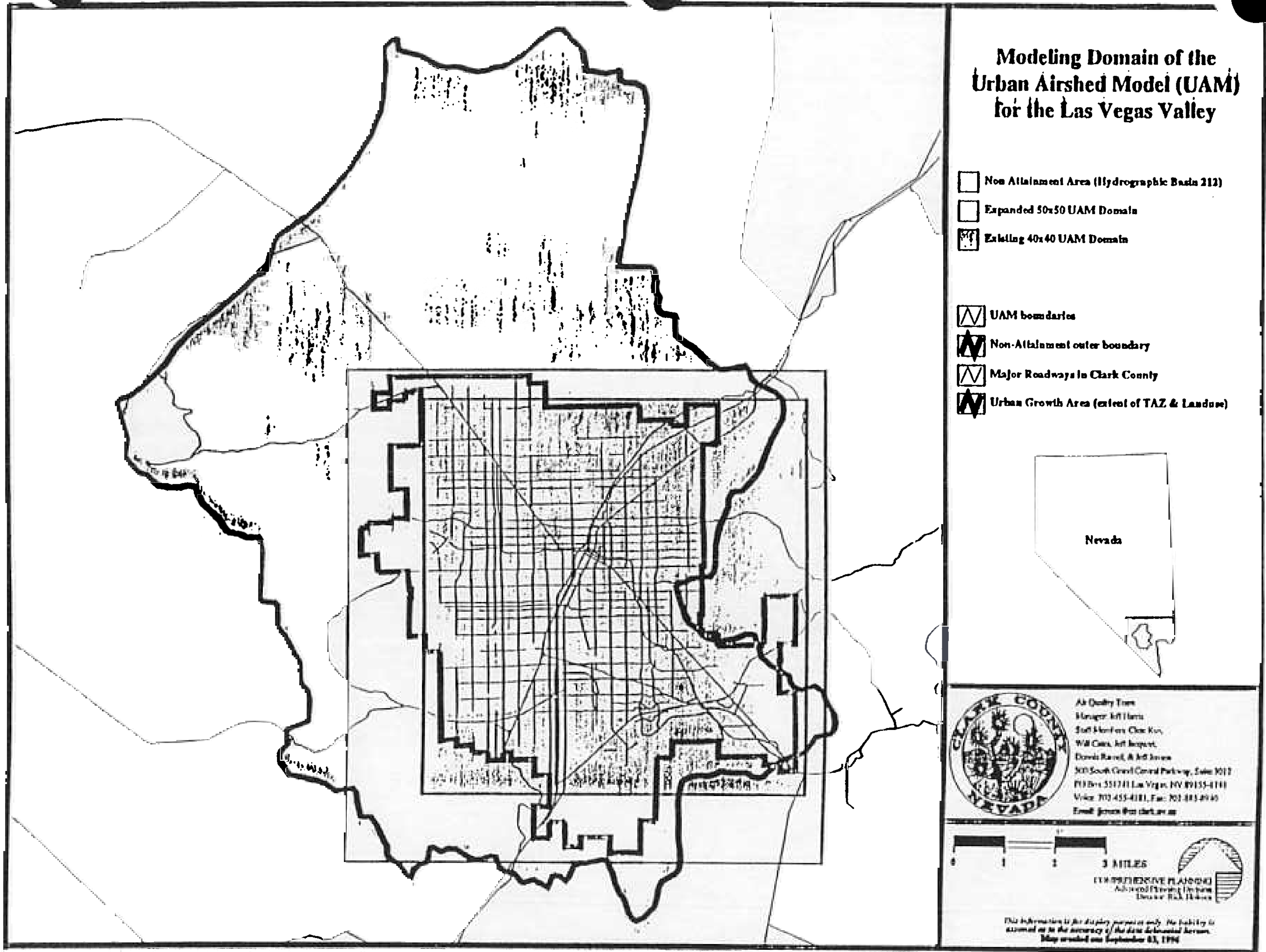

Figure 2-1. Las Vegas CO non-attainment area, with original and proposed UAM modeling grids overlayed.

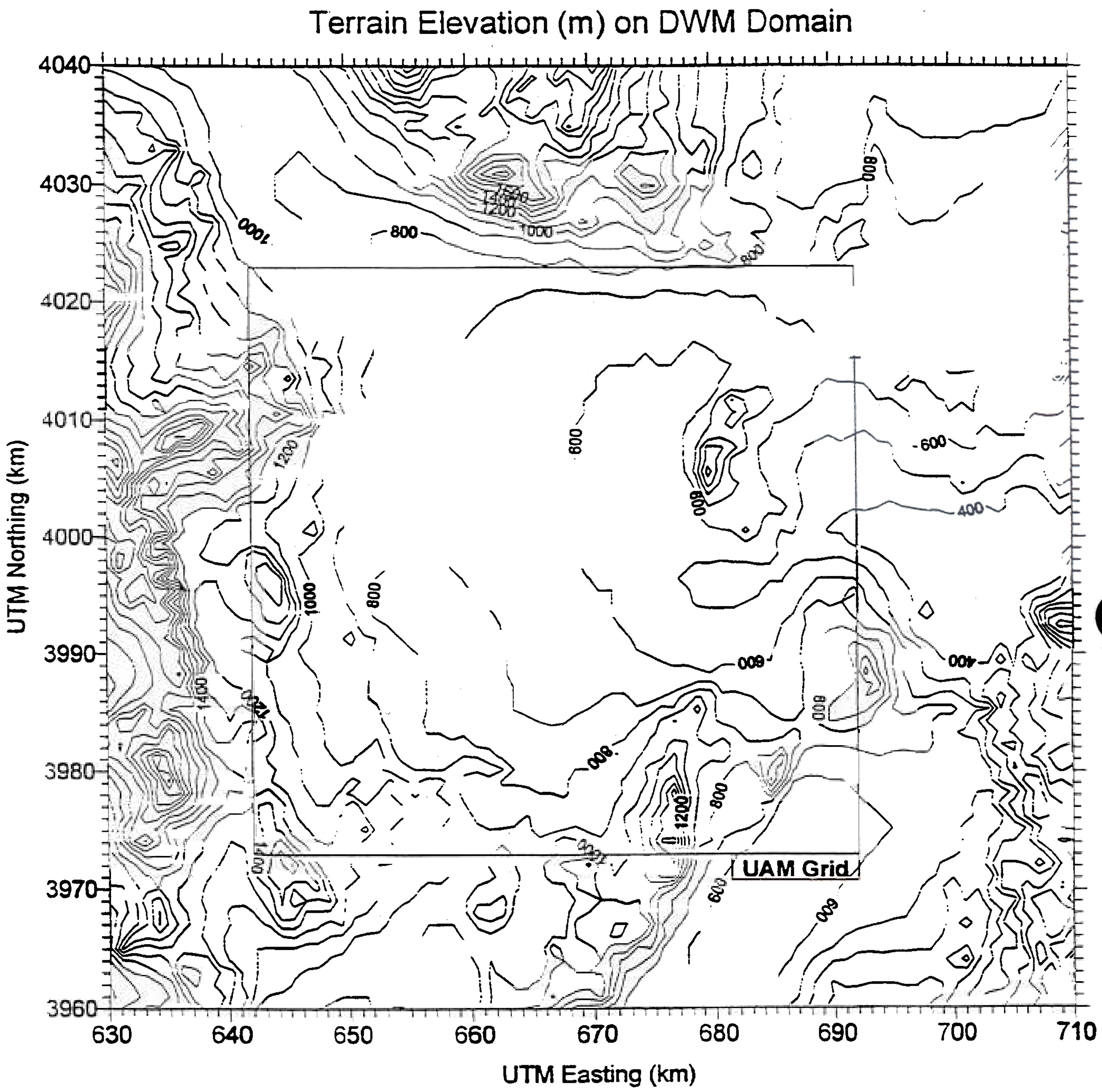

Figure 2-2. Las Vegas DWM modeling domain with smaller UAM domain superimposed (isopleths of terrain heights in meters).

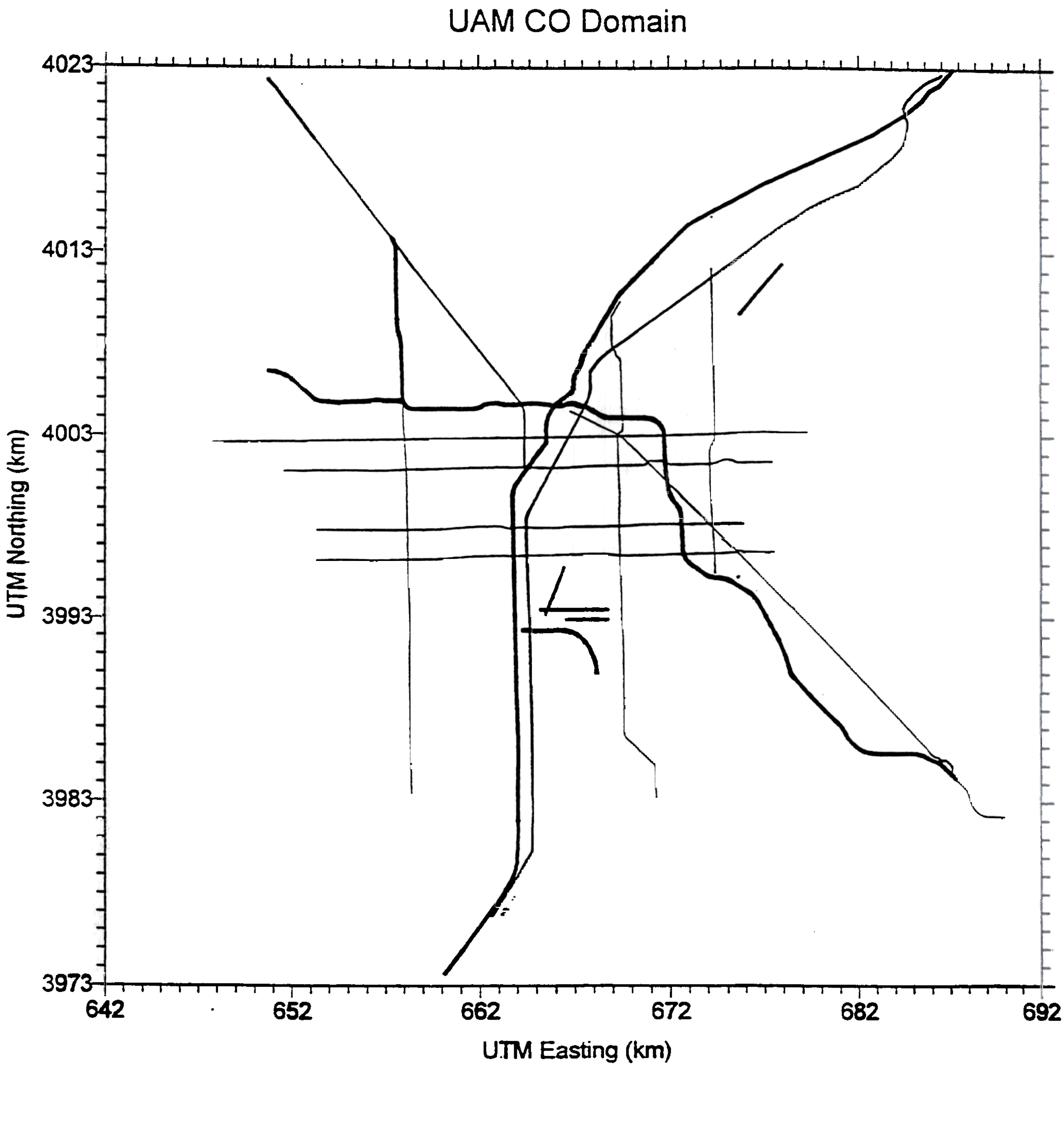

Figure 2-3. Las Vegas UAM modeling domain.

is available; (3) the diurnal trends show typical mid- to late-evening hour peak CO concentrations; and (4) the peak 8-hour concentrations indicate that high CO levels occurred at a number of monitoring sites. Final selection of one CO episode will be made by Clark County and the Clark County Health District.

UAM INPUT FILE PREPARATION

Emissions, meteorological, and air quality files will be developed in UAM format for the episode day identified during the episode selection task. Meteorological files will include UAM-formatted 3-D wind fields, 2-D surface temperature fields, and stability measures (e.g., vertical temperature lapse rates and exposure class). Air quality files will include UAM-formatted 3-D initial conditions, 2-D boundary concentrations, and 2-D top concentrations. All data files will be developed using data available from all available monitoring sites operating during the episode, as well as any special study data that may be available and applicable (see below).

UAM requires the following files:

SIMCONTROL	Specifies UAM run control parameters such as date and duration of simulation, file default and option information, and integration/chemistry time step size
CHEMPARAM	Contains information about the chemical configuration of UAM, including number and names of species to be simulated, definitions of reaction equations, reaction rate constants, upper and lower concentration bounds, and various chemical parameters
REGIONTOP	Defines the time- and space-varying depth of the UAM model grid
TERRAIN	Contains gridded surface roughness information and deposition factors
AIRQUALITY	Contains a gridded 3-dimensional definition of the initial concentration field for each species modeled
BOUNDARY	Contains a gridded time-varying definition of the lateral boundary concentration field for each species modeled
TOPCONC	Contains a gridded time-varying definition of the top boundary concentration field for each species modeled
DIFFBREAK	Contains a gridded time-varying field of the daytime convective mixing depth, or the depth of the nocturnal surface-based inversion
WIND	Contains a gridded time-varying field of horizontal wind
TEMPERATUR	Contains a gridded time-varying field of surface-level temperature

METSCALARS	Contains time-varying values of spatially-invariant meteorological parameters, including NO_2 photolysis rates, water vapor concentration, temperature gradients above and below the DIFFBREAK height, atmospheric pressure, and exposure class (a single measure of atmospheric stability and solar radiation intensity)
EMISSIONS	Contains gridded time-varying values of ground-level emissions for each species
PTSOURCE	Contains time-invariant point source stack parameters (location, stack height, diameter, exit velocity, exit temperature), and time-varying values of point source emissions and flow rates for each species

A SIMCONTROL file must be generated for each individual run of UAM. Assuming that episode selection results in a typical CO episode that extends over a single night, it is anticipated that the model will be started at 1500 LST on the first simulation day, and allowed to run through 1000 LST the following day. This follows from previous CO modeling for the LVV wherein sensitivity tests investigating impacts of initial conditions on peak 8-hour CO concentrations revealed little effect. The CHEMPARAM file will be set up to designate a single unreactive non-depositing CO species to be modeled. As described above, the REGIONTOP file will be set up to specify a time- and space-invariant model top at 200 m. The contents of the TERRAIN file are immaterial when modeling inert non-depositing species, but the file is required by the model. Space-invariant defaults will be supplied.

The initial concentrations field will be developed from all available CO measurements within the UAM domain at the start of the simulation. These will be interpolated to the modeling grid using a standard UAM AIRQUALITY preprocessor. Values near the boundaries will be set to low suburban values of 0.2 ppm, and concentrations above the DIFFBREAK height will be set to the clean tropospheric background value of 0.1 ppm, following the previous CO modeling approach. To investigate and ultimately alleviate any potential effects of initial conditions on model performance, two sensitivity tests will be performed. In the first, the model will be started one day prior to the first day of the episode and allowed to "spin up" to the episode period. This approach inherently assumes that the model will correctly reproduce CO patterns into the afternoon of the first episode day, leading to minimal impacts at times of predicted peak CO. In the second, the UAM will be started on the afternoon of the first episode day during an hour of minimum CO concentrations, with the spatial variation in observed CO as uniform as possible.

The lateral boundary concentration field will be developed using recommended background levels from the CO guidance document (0.2 ppm for suburban land use). There are no CO monitors within 10 kilometers of the boundary. While it is noted that the UAM boundaries are located in very rural desert terrain that could reflect clean tropospheric values (0.1 ppm), a higher value will likely reflect the basin-wide buildup of CO in the LVV over night. Nevertheless, a sensitivity analysis will be undertaken in which boundary concentrations are scaled up and down, and effects on resulting model performance noted. Following the previous CO modeling approach, concentrations above the DIFFBREAK height and above the model top will be set to the clean tropospheric background value of 0.1 ppm.

Meteorological and emission input files will be developed following the procedures discussed below.

Meteorological Modeling

Approach

The general approach in developing meteorological inputs for UAM will follow the steps and parameter settings used in modeling the December 7-8, 1990 episode. Sensitivity studies will be employed to investigate potential improvements to either the modeling methodology or the many tunable DWM parameters.

Meteorological files will be developed using the DWM, and possibly the MM5 (see below). DWM will first be configured using settings selected from previous CO modeling, and applied to the same 2 km DWM modeling grid. Results will be examined and compared to the conceptual model of meteorology under CO stagnation conditions. Direct observation-prediction comparison is not appropriate for wind fields generated by DWM as by definition diagnosed winds near observations should match (except in the case of several monitors within one grid cell). Sequestering data at one or several monitoring sites from DWM for the purposes of identifying DWM performance at those sites can often be a misleading practice. DWM performance is highly sensitive to the amount of data it is supplied, particularly in stagnant conditions where winds vary substantially from station to station; removing sites will likely lead to a different flow field in those areas, leading to an inconclusive performance evaluation. Therefore, DWM must be supplied the maximum available data to characterize the wind patterns where they are known. The process-oriented approach will be the best means of identifying model performance away from observations and within complex terrain surrounding the valley.

Sensitivity tests will then be run to investigate model behavior to changes in parameters that we feel are the most uncertain. A final set of DWM wind fields will be developed using optimal selections for parameters identified in the sensitivity tests. Wind fields generated by the initial and final DWM applications will be supplied to the UAM to investigate air quality sensitivity to wind field inputs. Both statistical and process-oriented model evaluations will be employed.

Depending on the quality and quantity of available meteorological data and upon the resulting performance of the DWM, MM5 may also be used to generate wind fields for UAM. If this is found to be necessary, it is currently envisioned that MM5 will be operated in nested mode; the coarse grid will likely span much of the desert southwest to account for large-scale (i.e. "synoptic") phenomena such as flow associated with the movement of high pressure centers over the area, while a nested grid approximately covering the DWM domain (adjustments to this grid may be necessary due to terrain) will be used to simulate flows associated with terrain-induced forcing, and stagnation in the Las Vegas Valley as forced by the large scale flows on the coarse grid. The nested grid would be configured to match the 1 km UAM grid spacing as closely as possible. Observations from the Valley will be incorporated into the MM5 4DDA system to ensure that model "drift" is minimized and to ensure that the resulting wind field matches observations as closely as possible in the area of concern.

Direct comparison of wind fields generated by DWM and MM5 will then be made; further, UAM CO predictions using MM5-derived winds will be compared with UAM CO predictions using DWM winds to ascertain any model performance gains. It is quite possible that MM5 will not perform any better than DWM for such stagnation episodes, particularly if incorporation of observations into MM5 via the 4DDA package dominates the results. In this regard, MM5 is equivalent to a mass- and energy-conservative observation interpolation scheme. Still, the obvious benefits of MM5 are that it produces a full suite of 3-D hydrodynamic fields (temperature, moisture, turbulence, mixing heights) that can only be intelligently "guessed" when applying DWM for the limited vertical data available in the Las Vegas Valley. We will also seek to superimpose measured stochastic wind variations on MM5 and DWM wind fields, to reflect chaotic wind patterns that cannot be addressed by these models (discussed in Section 3).

In the case of using DWM, estimates of mixing depth and inversion depth will be generated for the DIFFBREAK file by either analyzing routine NWS rawinsonde data from the Desert Rock site, or preferably using special field study tethersonde data (discussed below). In the former case, soundings from Desert Rock are available at 12-hour intervals and such tropospheric sounding data is quite coarse; diagnosis of hourly DIFFBREAK values from such data is nearly equivalent to guesswork. In the latter case, the tethersonde data offers much better resolution in both time and height, allowing very accurate diagnosis of inversion depth during the night. In any case, due to limitations in simulating the collapse of the boundary layer and growth of the nocturnal inversion layer, it will be difficult to accurately specify the time variation of DIFFBREAK values in early evening and late morning. If the only data available for Phase I modeling is from Desert Rock, we will use the DIFFBREAK values specified in the previous modeling work. If tethersonde data is used, temperature and wind profiles will be analyzed to obtain the best estimate of DIFFBREAK height; it will be assumed that the values are spatially invariant and apply throughout the entire LVV.

The most important parameters carried by the METSCALARS file are the temperature gradients above and below the DIFFBREAK height. These, in concert with exposure class, control the rate of mixing across layers, which becomes crucial during nighttime stagnation. Similar to the problems associated with specifying DIFFBREAK, a highly resolved vertical sounding data set is required to accurately specify temperature gradients. If only data from Desert Rock is available, we will use the values specified for the previous modeling work; otherwise these will be easily obtained from the tethersonde data. Exposure class from the previous modeling will be used. Atmospheric pressure, water vapor, and NO_2 photolysis rate constants are not required in inert CO modeling, and so will be assigned default values.

The TEMPERATURE file is primarily used for reactive UAM applications, but it may affect some vertical mixing parameterizations. The UAM code will be reviewed to verify that ambient temperature (other than the vertical temperature gradients) are not used in controlling the rates of vertical mixing. If this is the case, a dummy TEMPERATURE file will be generated; if temperature is used for processes other than chemistry and deposition, then a TEMPERATURE file will be developed using standard UAM preprocessors and all available data from the region.

Input Data and Use of Special 1994 Field Study Data

The meteorological data available from the APCD and National Weather Service has been reviewed in Section 1. While surface data coverage is obviously much improved over the database available for the December 1990 episode UAM application, serious limitations continue to exist in regard to routine upper air measurements with adequate time and vertical resolution. This major data gap will be remedied during the Phase II intensive field study during the winter CO season of 1996/97.

However, a potential remedy for Phase I work currently exists in a database developed by DRI during a December 1994 tracer gas experiment in the LVV. During that field exercise, several more surface monitoring sites were established along with a tethersonde site that measured winds and temperature profiles up to several hundred meters. Unfortunately, while a few periods of high hourly CO occurred during the field study, the 8-hour standard was not approached. It is quite possible then, that meteorological conditions were not so severe as to be fully representative of an exceedance event.

An analysis of all available field data taken during the marginal CO events of December 1994 will be undertaken. In particular, 1994 episode APCD CO and meteorological data will be analyzed and compared to conditions during the winter 1995/96 CO events to ascertain to what degree the patterns match and agree to the conceptual model for LVV. If a high level of matching is apparent between events of 1994 and 1995/96, then we will have confidence that the 1994 DRI special field data adequately represent the LVV CO regime. These extra data will then be utilized in the development of UAM input files for the Phase I modeling of a 1995/96 CO event.

Quality Assurance Procedures

The purpose of quality assurance procedures is to uncover potential data input gaps that, when corrected, lead to improved model results. These steps give the modeler some measure of confidence in the ability of the model to capture key meteorological features in order to predict spatial and temporal distributions of CO during stagnation events. One of the most useful tools includes graphical displays of gridded meteorological fields with observations superimposed where available. This allows for a visual inspection for any obvious problems in the fields, as well as for a basis for comparison to a conceptual model of the drainage flow regime that sets up under CO episodes. Initial UAM applications with a first-order quality assured set of inputs often reveal input errors not seen in the first scan that require further correction.

EMISSIONS MODELING

For the base case modeling of the 1995/96 winter season, the episodic emissions inventory will be developed from 1995 emissions data following EPA emission inventory preparatory guidelines. These guidelines cover the estimation and projection of emissions as well as the procedures for developing emissions for UAM modeling applications. The EPA guidelines are contained in the following documents.

Emission Inventory Requirements for Carbon Monoxide State Implementation Plans (EPA, 1991a)

Procedures for the Preparation of Emission Inventories for Carbon Monoxide and the Precursors of Ozone, Volume I (EPA, 1991b)

Procedures for Preparing Emissions Projections (EPA, 1991c)

Procedures for the Preparation of Emission Inventories for Carbon Monoxide and the Precursors of Ozone, Volume II: Emission Inventory Requirements for Photochemical Air Quality Simulation Models (EPA, 1992a)

Procedures for the Preparation of Emission Inventories, Volume IV: Mobile Sources (EPA, 1992b)

Guideline for Regulatory Application of the Urban Airshed Model for Areawide CO Applications (EPA, 1992)

Publicly available, emissions processing models will be used to calculate emissions and to format data for UAM modeling in accordance with EPA guidelines. These models are summarized below.

MOBILE — MOBILE (current U.S. version is MOBILE5aH) is the U.S. EPA's on-road emission factor program for hydrocarbons, carbon monoxide and nitrous oxides. MOBILE predicts on-road emission factors in grams per mile traveled under episodic conditions.

DTIM — DTIM (current version DTIM2) is a mobile source emissions allocation model used to evaluate spatially and temporally allocated mobile-source emissions inventories. DTIM, developed by the California Department of Transportation, combines travel demand model data (providing link-based activity) and emission factor models (providing mass per activity emission rates) to produce hourly, gridded mobile source emissions.

EPS — EPS (current version EPS2) is an EPA sponsored emission inventory development system. The system prepares anthropogenic (area, point and mobile sources) and biogenic emission inventories for air quality modeling applications. The system is used to develop episode-specific inventories including spatial allocations, temporal allocation, and hydrocarbon speciation.

MOBILE will be used to generate episodic, mobile source emission factors. These emission factors along with transportation demand model activity data will be processed to generate the mobile source emission inventory. EPS2 will be used to calculate area and point source emissions and to combine the mobile, area and point source inventories into a single inventory formatted for UAM modeling. This sequence of events is summarized in Figure 2-4. Figure 2-4 also illustrates the incorporation of emissions modeling data into the inventory development process. Locally derived modeling data will be incorporated into the emission inventory development. The agencies from which data will be obtained are listed in Table 2-1.

Quality Assurance Procedures

Emission factors, activity and emissions estimates will be thoroughly examined for accuracy of computational procedures at each step in the emission inventory development process. In addition, emissions summaries by source category will be examined for reasonableness and completeness through comparison to previous estimates for the same region. Sources of previous estimates will be the *Regional Interim Emission Inventories* (EPA, 1993) and the UAM modeling study for Clark County completed by BRW and SAI (1992).

Table 2-1. Clark County agencies supplying emissions modeling data.

Agency	Data
Regional Transportation Commission	Link based activity data from the travel demand model (TRANPLAN) for the 1995 base year
	Mobile source diurnal, monthly, day-of-week activity data
	land use data for 1995 and future scenario years
Health District, Air Pollution Control Division	1995 annual point source emissions inventory
	1995 annual area source emissions inventory
	Area and point source temporal allocation data
Department of Aviation	CO emissions inventory for McCarran International Airport

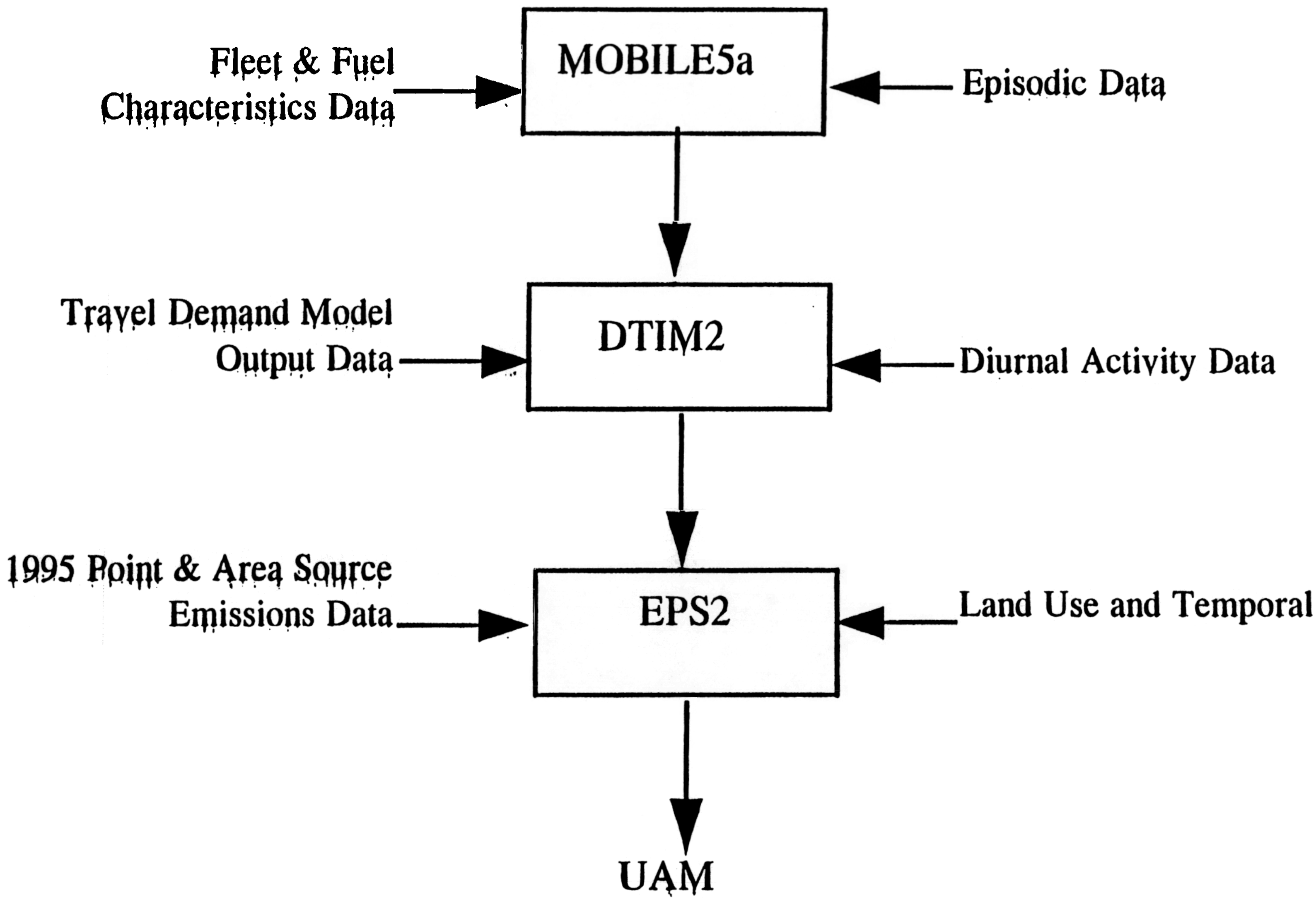

Figure 2-4. Overview of programs and data that will be used to develop emissions inventories.

3 PHASE I UAM BASE CASE PERFORMANCE EVALUATION

ENVIRON will review all UAM input files, including emissions, meteorological, and initial/boundary fields, prior to all UAM-IV simulations. As discussed in Section 2, meteorological fields will undergo several quality assurance steps, as well as a complete performance evaluation and intercomparison between DWM and MM5 results (if necessary). Initial and boundary conditions will be plotted and compared to the observations that were used to generate them. Emissions will be quality assured by plotting hourly spatial maps of emission densities, and tabulating the point source emission rates. The UAM will be exercised only after confidence in all input fields is achieved.

Initial UAM applications may reveal certain input errors or problems that were not exposed by the quality assurance procedures. Base case UAM runs will not be attempted until these problems are corrected. Additional diagnostic sensitivity tests will be performed to understand UAM response to changes to various parameters known to be the most influential on CO predictions. At a minimum, these will include tests of varying diffusion break heights, and emission estimates. As discussed in Section 2, sensitivity to initial conditions will be investigated by altering the length of the model spinup period; contributions of initial and boundary conditions to hourly CO patterns will be determined by specifying zero emissions and running UAM with just initial conditions, and running with just boundary conditions. UAM sensitivity to winds will be investigated in tests that utilize the several DWM wind fields, and possible MM5 fields. All diagnostic steps will be documented and reported to Clark County and the Project Oversight Committee.

UAM performance in predicting CO throughout the Las Vegas modeling domain will be evaluated using statistical, graphical, and process-oriented methods. As described in Section 1, the adequacy of the existing monitoring network will be assessed to ensure that a reasonable degree of confidence may be placed on the resulting statistics.

PROCESS-ORIENTED MODEL EVALUATION

It is understood that all air quality and meteorological models have inherent limitations and weaknesses that restrict the range of their applicability and affect their ability to replicate actual conditions. Furthermore, the input data required by the models also have limitations, uncertainties, and inaccuracies that ultimately affect model performance. It has been, and will continue to be, very difficult to separate the affects of these two sources of modeling uncertainties.

While imperfect, air quality grid models represent the best planning tool available for assessing the response of air quality to changing urban and regional airborne emissions. Careful evaluation and analysis of these models is needed to minimize the risk of being mislead by the model results and for avoiding ineffective but expensive mitigation strategies. Advanced model performance evaluations traditionally have been built on statistical comparisons between model predictions and observations of parameters. While statistical evaluation methods provide quantitative measures of performance, they often shed little or no light on the reasons for poor model performance. Nor do statistical evaluations provide any indication of the robustness of apparent good performance. Therefore, traditional model performance evaluations typically leave the user without a clear picture of a model's reliability or applicability to a particular situation. Nevertheless, statistical evaluation remains a useful component of the overall model evaluation process to provide a quantitative assessment of model performance that can be compared with past model applications.

Recent successes in understanding the performance of predictive models (both advanced air quality and meteorological models) in urban- and regional-scale studies have been achieved by process-oriented model evaluation. We favor a particular type of process-oriented evaluation that focuses on comparisons of model predictions with observation-based conceptual models of the processes which played important roles during modeling episodes.

Conceptual models should offer a general description of what "probably" occurs during various types of episodes. These descriptions provide a framework on which we can unravel the cumulative uncertainties created by the inherent limitations and simplifications of the models' formulations and the resolution, density, accuracy, or representativeness of the models' input data. Interpretation by experienced air quality scientists of all available data (especially when obtained from carefully designed supporting monitoring studies) can often yield a qualitative or conceptual description of the dominant physical and chemical processes that occurred during an episode of interest. Of course, like any model, conceptual models are imperfect and occasionally hyper-speculative, so they must be used with considerable discretion. Nevertheless, significant deviations in numerical model predictions from those expected on the basis of a relevant conceptual model, are indications that something could be seriously wrong with the predictive model, the conceptual model, or both. The process of reconciling differences and exploring areas of agreement between predictive and conceptual models yields a more informative assessment of predictive model performance and applicability than statistical performance evaluation alone can afford. Therefore, we would validate the Las Vegas CO modeling system using both traditional statistical model evaluation methods as well as a "process-oriented" evaluation.

STATISTICAL AND GRAPHICAL EVALUATION

The minimum set of statistical parameters will include: unpaired peak prediction accuracy, normalized and fractional bias, and normalized and fractional gross error of all observation-prediction pairs above 4 ppm CO. The emphasis in the statistical portion of the modeling tasks is to evaluate the ability of UAM to reproduce magnitudes, timing, and trends that are observed to take place from the available measurements. Acceptable model performance will be determined by the standards set by EPA guidance.

Graphical methods will include at a minimum:

1) Time series plots comparing hourly and 8-hourly average predicted and observed CO concentrations at each monitoring site over the coarse of each modeling episode;
2) Surface isopleths of peak hour, selected hourly, and 8-hourly average CO distributions,

with corresponding observed CO concentrations overlayed at locations of monitoring sites;
3) Scatter plots of predicted vs. observed hourly CO concentrations;
4) Tables of paired peak predicted and observed CO concentration at each monitoring site
5) Two-dimensional color animation of the evolution of predicted CO distributions, with overlayed observations at each monitoring site location.

SENSITIVITY STUDIES AND POTENTIAL UAM IMPROVEMENTS

Experience in past CO modeling projects (e.g., Phoenix, Los Angeles, and review of CO modeling in Las Vegas) has revealed that certain aspects of the UAM are inappropriate for modeling stagnant, highly stable environments unique to CO episodes. These are primarily related to the use of the diffusion break to determine the extent of vertical mixing, and the use of constant hourly-average winds. The following subsections present some analyses of potential improvements to the UAM that may treat CO episodes in a more precise manner. Descriptions of sensitivity simulations to these modifications are presented.

Sensitivity to Vertical Grid/Vertical Diffusion

The diffusion break was originally designed for ozone applications in which all pollutants are mixed through a deep afternoon mixed layer, but emissions are trapped within a shallow nighttime stable layer and decoupled from older pollutants aloft. The diffusion break represents the top of the neutral/unstable mixed layer during the day, but represents the top of the stable inversion layer during the night and early morning. This is accomplished in the model by increasing the diffbreak height during the day to some estimated peak, then lowering it in the evening to some minimum during the early morning hours.

The specification of diffusion break height is crucial in CO modeling, and has been found to be a very effective "tunable" parameter to adjust CO peaks to just about any value the modeler requires. The effect is to squeeze emissions into a thin near-surface layer as the diffusion break height is lowered during the evening; specification of stable lapse rates and negative exposure class effectively shuts any vertical exchange between layers below or (obviously) above the diffusion break height. In the case of a minimum 80 m deep diffusion break with four layers, most emissions (as most result from area sources) are trapped within the first 20 m deep layer, with only "old" low-concentration CO above this level.

In fact, the specification of diffusion break in this manner is inconsistent with the actual processes associated with the evening breakdown of a well mixed layer concurrent with the buildup of a surface-base nighttime stable layer. This transition between deep afternoon mixed layer to shallow evening stable layer is a complex process that cannot be described simply as a lowering of the diffusion break height. The deep afternoon mixing layer depth remains high into the evening as turbulence dissipates; meanwhile, after sunset a surface-based inversion develops from the ground up, and grows in height during the night. Obviously, reducing the diffusion break during the night starts the stable layer too deep in the early evening, and moves the top of the stable layer in the wrong direction with time. Unfortunately, there is no way to properly specify the time rate of change of the diffusion break within the current UAM formulation to properly account for this phenomena. Effectively, the UAM needs to be modeled as a three-layer system (surface based layer, old mixed layer, aloft layer) in which each layer thickness may change independently and oppositely, rather than a two-layer system (surface based layer vs. elevated layer).

The easiest and most effective way to remedy this problem is to use a fixed grid of ample resolution and control the rates of diffusive transfer between each layer explicitly. We propose to accomplish this by using UAMX as a test bed and developing turbulent exchange coefficients from the available meteorological fields. The development of surface-based stability with height is more realistically controlled in such a manner, as is the eventual decay of turbulence and diffusive fluxes aloft during the evening. Impacts to model performance will be noted and a full technical discussion with our recommendations to the Project Oversight Committee will be documented.

Sensitivity to Horizontal Resolution

The UAM is designed to simulate the emission, dispersion, and chemical reactions of pollutants within an air basin at resolution in the low end of the mesoscale (i.e., grid sizes of a few kilometers minimum). This is primarily driven by the use of UAM to predict daytime ozone levels, in which the scales of motion and chemistry are on the order of 2-5 km, and many models used to prepare meteorological inputs are applicable only at such scales. For stagnant CO episodes, scales of motion are much smaller, chemistry is insignificant, and local sources may dominate areawide CO distrubutions. Therefore, specification of the finest grid size as practical improves the emissions distribution, while potentially improving the representation of the meandering properties of the drainage-dominated wind field.

The UAM may be run to evaluate the effects of including a finer grid over the area of interest within the standard UAM grid developed for the LVV. If higher resolution is seen to substantially improve performance and is deemed useful, then we will consider either (1) running the UAM in a one-way nesting configuration in which the UAM is first run on the standard grid and supplies boundary conditions for a run on the finer grid; or (2) reducing grid size over the entire modeling domain.

Sensitivity to Introduction of a Stochastic Component

Most, if not all, operational air quality models operate on an hourly basis, i.e., input fields are read each hour and held constant for the duration, while the model integrates forward each time step (typically 5-20 minutes) and outputs hour average concentrations. The use of hour-average wind fields (and to a lesser extent stability and temperature) has many drawbacks when modeling CO stagnation events. First, many observations are not hourly averages, and are in fact instantaneous observations from such facilities as airports. Second, stagnation conditions are characterized by very light winds with very large directional variability. Depending on anemometer sensitivity, such conditions are often reported as absolute calms (0 wind speed). The stochastic nature of the real wind fields is a dominant component during stagnation as the presence of weak turbulent eddies are not masked by strong mean flow forcings. Models such as DWM and even MM5 cannot accurately reproduce such stochastic influences as these effects develop from forcings that are much too small to be resolved. The net effect is to artificially move mass on the grid in a constant pattern for the duration of an entire hour.

Further, deterministic meteorological models tend toward organizing flow patterns when in actuality the wind patterns are highly disorganized and transient. This may be a very strong reason why certain consistent biases develop between observed and predicted CO patterns.

We propose to evaluate the potential influence of this problem on UAM performance by incorporating a stochastic component to the wind fields. This will be accomplished in two possible ways using the UAMX as a test bed. First, hourly input wind fields could be adjusted at each time step and for each grid cell by adding an individual random turbulent component that is extracted from a lookup table. The table of turbulent components will be calculated using a Monte Carlo type of approach, in which a Gaussian probability density function is defined using observed wind statistics (if available). A maximum time step duration will be set to ensure that the resulting hourly average wind in each grid cell is not improperly biased away from the input mean (a likely time step will be 1-5 minutes). A lookup table must be used so that identical modifications to the wind fields is achieved when repeatedly running the UAM-IV for many emission scenarios.

Second, 1-, 5-, or 10- minute wind data could be used (if available) to generate input wind fields at fine time resolution, rather than hourly. In this way, the wind fields would include the natural measured temporal variations associated with a much smaller time scale. This approach is critically dependent on the number of wind sites at which minute-by-minute data are stored and available. Further, this second approach could not address the spatial variability in the wind fluctuations that occur away from the wind measurements, except, for example, through the DWM interpolation process.

A similar approach to these two options would be to adjust the horizontal diffusion rate (currently "hardcoded" as a single constant value), but this is seen to be too arbitrary, and would uniformly affect the entire grid for the duration of the simulation. Impacts to model performance will be noted and a full technical discussion with our recommendations to the Project Oversight Committee will be documented.

Staff at the APCD have reviewed the monitoring station operations. Although hourly data is provided in their database, 10-minute average air quality and meteorological data are stored on site. Several years of data are available in this manner. APCD will provide these data to the modelers in ASCII format, with a full description of the data fields and formats.

Sensitivity to Preliminary EPA Off-cycle CO Emission Estimates

Currently, MOBILE does not include all sources of on-road vehicular CO emissions. A significant amount of CO emissions result from driving behaviors not accounted for in the model. In particular, the maximum rate of acceleration used in standard emission testing driving cycles is lower than the maximum rate observed in-use. Acceleration and other driving behavior can greatly affect the emission rate of a vehicle, especially during particular modes with extra load or enrichment. The EPA is completing work to quantify the effect that this omission is having on mobile source inventory estimates. The emissions not included in the current model's driving cycles are commonly called *off-cycle emissions* or *in-use driving effects*. These two terms are used interchangeably.

The U.S. EPA Office of Mobile Sources (EPA OMS) has completed a preliminary estimate of off-cycle CO emissions. This estimate was originally developed for inclusion with the MOBILE5b model (soon to be released). Upon further review, however, EPA OMS decided that testing in support of MOBILE6 would further refine this estimate and that off-cycle emissions would not be included in MOBILE5b. Because the EPA OMS decided to exclude off-cycle emissions from MOBILE5b, we determined that it would be most appropriate to include off-cycle CO emissions as a sensitivity analysis and not as part of the base case emission inventory development.

In this sensitivity analysis, we will follow the preliminary EPA OMS methodology exactly in modifying the MOBILE5a emission factors. This methodology is presented in Appendix A to this protocol containing a written copy of the preliminary EPA OMS methodology. The modified emission factors will be processed through DTIM2 and EPS2 in the same manner as the base case inventory in order to get a modified emissions inventory. The UAM model performance will then be tested for sensitivity to the modified emissions inventory.

4 MICROSCALE HOT SPOT MODELING WITH CAL3QHC

CAL3QHC is a microcomputer based model used to predict carbon monoxide (CO) or other inert pollutant concentrations from motor vehicles at roadway intersections. CAL3QHC combines the CALINE-3 line source dispersion model with a traffic algorithm for estimating vehicular queue lengths at signalized intersections. CAL3QHC is the most widely used intersection model for hot spot evaluations and is the recommended model by the U.S. EPA.

CALINE-3 was designed to predict air pollutant concentrations near highways and arterial streets due to emissions from motor vehicles operating under free flow conditions. However, it does not permit the direct estimation of the contribution of emissions from idling vehicles. CAL3QHC enhances CALINE-3 by incorporating methods for estimating queue lengths and the contribution of emissions from idling vehicles. The model permits the estimation of total air pollution concentrations from both moving and idling vehicles. It is a reliable tool for predicting concentrations of inert air pollutants near signalized intersections. Because idle emissions account for a substantial portion of the total emissions at an intersection, the model is relatively insensitive to traffic speed, a parameter difficult to predict with a high degree of accuracy on congested urban roadways without a substantial data collection effort.

In 1992, CAL3QHC Version 2 was released, and it incorporated revised methodologies for the estimation of intersection capacity, delay, and queue lengths. In addition, Version 2 included three new optional traffic parameters (saturation flow rate, signal type, and arrival type) and had increased link and receptor modeling capacities. The most recent version of CAL3QHC appeared on the EPA's bulletin board in October 1995. This version allowed for more flexibility in the format of modeling inputs. We will use the latest available version of CAL3QHC.

Methodology for Using CAL3QHC with the UAM

Hot spot modeling will be completed following EPA modeling guidelines. These guidelines cover the analysis procedures, intersection selection, receptor siting and emission factor estimation. The EPA guidelines are contained in the following documents.

User's Guide to CAL3QHC Version 2.0: A Modeling Methodology for Predicting Pollutant Concentrations Near Roadway Intersections (EPA, 1995)

Guideline for Modeling Carbon Monoxide From Roadway Intersections (EPA, 1992c)

Estimating Idle Emission Factors Using MOBILE5 (EPA, 1993)

The EPA guidelines recommend the combined use of CAL3QHC (Version 2.0) and area wide models, such as the UAM, for overall urban area analysis. In brief, the UAM predicted concentration is combined with those of CAL3QHC to determine the maximum microscale concentration. The CAL3QHC model is run using the UAM hourly temperature, wind speed, and wind direction from the grid square where the intersection is located for each hour of the episode being modeled. The UAM predicted CO concentration from the grid cell where the intersection is located is entered into the CAL3QHC model as the background concentration to determine the total impact for each hour. The results can then be averaged over a running 8 hours to determine the maximum 8-hour concentration.

CAL3QHC input parameters include roadway geometries, receptor locations, meteorological conditions and vehicular emission rates. In addition, several other parameters are necessary, including signal phasing and cycle length data and information describing the geometric configuration of the intersection being modeled. These data requirements and the sources that will be used in this study are summarized in Table 4-1.

Purpose of the CAL3QHC Modeling

CAL3QHC modeling will serve two purposes in this study. Firstly, the model will be used to determine if any areas of the modeling domain are out of compliance with the CO NAAQS. Secondly, CAL3QHC modeling will be completed, as needed, to determine if there is a significant microscale contribution to actual CO monitor measurements that may be causing an underprediction of the UAM. These two purposes are discussed below.

As described in the EPA guidelines (EPA, 1992c), the primary purpose of CAL3QHC modeling is to determine if any areas of the modeling domain are out of compliance with the CO NAAQS. The methodology of combining microscale concentrations with grid cell background concentrations is to be completed for those high-volume intersections located in high background concentration cells. Based on this criteria, it is anticipated that modeling will be completed for the "Five Points" region of Las Vegas as was done in the 1992 AQIP (BRW and SAI, 1992), and also at Flamingo and Las Vegas Boulevard. After reviewing the UAM modeling results, we may model additional intersections if it appears that the standard could be violated elsewhere in the modeling domain. This modeling is completed because the UAM model averages emissions over an entire grid cell, and thus is not an accurate predictor of violations of the CO NAAQS caused by microscale conditions. There have been concerns in the past that to some degree, combining model estimates in this way results in double-counting emissions (as the link emissions are included in both models); however, traffic models that provide the UAM with mobile source emissions reflect link running emissions from point to point, while CAL3QHC mainly reflects emissions from stopped vehicles at individual intersections.

In addition, CAL3QHC will be used, as needed, to estimate the impact of nearby roadways on actual monitor site concentration measurements. This will be completed for monitors that meet the following criteria: (1) the monitor has observed high CO measurement at or over the CO NAAQS, (2) the monitor is near heavy, local traffic and (2) the UAM model is consistently underpredicting monitor measured concentrations. This modeling may be needed for monitors that are influenced by microscale conditions not adequately modeled by the UAM. If this is found to be the case for a monitor, then the microscale contribution will be completed for all modeling scenarios.

Table 4-1. Hot spot modeling data requirements and sources.

Data	Source
Traffic volume and intersection configuration	Intersection configuration and traffic data will be obtained from the Regional Transportation Commission
Meteorological conditions and background concentrations	Meteorological data will be consistent with UAM episodic modeling.
Emission factors	Emission factors will be obtained using MOBILE5aH following EPA guidelines and will be consistent with episodic modeling conditions used to develop UAM emission inventories.
Site selection and receptor location	EPA guidelines will be followed.

5 PHASE II FIELD DATA COLLECTION ACTIVITIES

As a general rule, better model performance and higher confidence in model predictions are achieved as availability and quality of meteorological, air quality, and emission measurement data increase. Advanced air quality and meteorological grid models can and have been applied to areas where little observational and emission information is available, but in these cases modeling uncertainties are high and reliability of the modeling is low. Confidence in modeling is at its highest where modeling efforts are linked to observational programs that are carefully planned and designed explicitly to support the needs of modeling. It is the purpose of the proposed supplemental observational program to improve the reliability of the air quality modeling system for the Las Vegas region.

There is practically no limit on the amount of money that could be spent on monitoring in attempting to reduce model uncertainties. However, as in any study of this type, financial resources are limited and a balance must be struck in allocation of funds between the monitoring and modeling efforts. Ideally, plans for an observational study should optimize the cost effectiveness of data collected for the purposes of model input preparation and model evaluation. The plan should also make optimal use of existing monitoring, previous as well as extramural resources. Ultimately, sufficient resources must remain for an appropriate level of data analysis, conceptual model development, and for model adaptation, set-up, testing, process-oriented evaluation and training. We would seek to find an appropriate and practical balance between these competing demands on resources in designing our field study plan.

The objectives of Phase II of the proposed study include the following:

- Design a winter field study to collect the data necessary to provide model inputs and data for model evaluations.
- Perform the winter field study and provide the data to the model and to Clark County.
- Prepare emissions for selected episodes during the winter field study.

Note that this task must start early enough to permit the research team to be in the field collecting data by December 1, 1996, but start late enough in order to benefit from the modeling and analyses to be performed in Phase I. Since new sites will likely be required, at least 1-2 months are needed in order to identify and secure new sites, to install equipment and perform startup activities in order to be operational by December 1, 1996.

PREPARATION OF FIELD DATA COLLECTION PROTOCOL

Based on our current understanding of the air quality and meteorological characteristics of the Las Vegas Valley, a field study will be undertaken to address the data needs for modeling, including additional surface CO and meteorological sites to fill gaps in the existing network and upper-air meteorological soundings to collect data above the surface. The field study will consist of the following components:

The existing CO monitoring network of 12 sites;
3 additional CO monitoring sites;
The existing surface meteorological monitoring network of 14 sites;
The existing NWS twice-daily rawinsonde soundings at Desert Rock northwest of Las Vegas;
2 doppler acoustic sounding systems (DAS) located in the Las Vegas Valley to measure upper-air winds;
One radar wind profiler with radio acoustic sounding system (RASS) to measure upper-air winds, temperature, and mixing height (to be collocated with one of the DAS); and
Additional surface meteorological monitoring at the new CO and DAS sites.

The required deployment of equipment and their locations will be determined during Phase II-Task 1 using results of the model evaluation in Phase I. In consultation with the Project Oversight Committee, a monitoring plan will be developed that will provide procedures for data collection, processing, validating, and reporting including recommended quality assurance procedures for generating data with known accuracy, precision, and validity. The Plan will cover: the data needed for modeling, the equipment required to collect the needed data, the locations, time, and frequency for data collection, and the recommended time-period for the winter study.

INSTRUMENT DEPLOYMENT, DATA COLLECTION, AND DATA PROCESSING

CO and Surface Meteorological Measurements

The CO monitoring and surface meteorological data collection network operated by the Air Pollution Control Division (APCD) of the Clark County Health District has fairly good coverage in the Las Vegas Valley. Several stations are located in the immediate vicinity of East Charleston Boulevard for small scale spatial resolution of CO. Other stations measure CO on the neighborhood scale representing moderately large areas in their vicinity.

DRI will be responsible for deploying and operating the CO, surface meteorological, and 50-100 m meteorological measurement systems. In designing the proposed field study, we planned the new CO and surface meteorological monitoring sites to fill gaps in the existing network. Other alternatives will be evaluated during the planning phase to see if they provide data to better meet project objectives. One such alternative might be the use of many more (possibly as many as 30) personal CO monitors hung on telephone or light poles to understand the gradients in CO around existing monitors and in new areas. Integrated Environmental Systems (IES) has agreed to be a member of our team and provide their monitors to the study if needed. The monitors, manufactured by National Draeger, Inc., can collect and store one-minute CO concentrations for approximately 24-48 hours before the data needs to be downloaded. Previous studies have identified temperature and some chemical interferences; however, these studies also demonstrated solutions to these problems. It is possible that deploying the personal CO monitors as saturation samplers might provide better data for modeling.

The following describes the general monitoring plan:

1) Equipment required to collect data. Standard continuous CO monitors and meteorological instruments will be used to provide satisfactory temporal coverage with minimal operational effort. This will require the proper placement of the monitors to minimize local interferences and siting costs. Wind speed and direction and temperature will be measured on 10-m towers near the CO sites.

2) Locations for data collection. It is anticipated that three CO monitors and surface meteorological stations and two elevated meteorological stations will be added to the network for a 60-day period to enhance the spatial coverage. The exact locations will be determined following Phase I. Possible site are discussed below.

3) Time and frequency of data collection. CO and surface meteorological data will likely be collected from continuous analyzers as one-hour averages, although the averaging period could be shortened to 15-minutes. Data acquisition systems will be deployed to collect data from each continuous instrument.

4) Time for data collection. The high CO season generally occurs from November through February with the highest CO during December and January. A 60-day period will cover the December-January time and will likely have, depending on meteorological conditions, 3 or 4 high CO episodes. The plan could include a provision to interrupt the field measurements if it is predicted that the meteorological conditions will not be conducive to high CO for a period of a week or more. Such an interruption would allow for data collection to occur over a longer period than 60 calendar days with a minimal amount of extra cost.

The following discussion outlines the reasoning for the deployment of additional CO monitors and meteorological sensors to enhance the current monitoring network and the anticipated locations. This will be further defined in Task 1. The operating procedures are also summarized.

Site Deployment

To lower cost of deployment and operations, locations will be found in which CO analyzers can be placed in existing protected environments and still have access to measure ambient CO. The deployment will be such that no nearby sources will directly impact the instruments and that EPA siting criteria (40 CFR 58, Appendix E - "Probe Siting Criteria for Ambient Air Quality Monitoring") can be followed as closely as possible.

Routine measurements have shown that high CO concentrations occur at the E. Charleston site while special studies[1] have confirmed that high CO extends from 1 to 2 km, and possibly more, to the north, east, and south of the site where the terrain, local sources, and transport from

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[1] Bowen, J.L. and R.T. Egami (1994) "Clark County Carbon Monoxide Hotspot Study" Final report prepared for Clark County Health District, DRI Document NO. 6460-684-4010.1F1, Nov. 10, 1994

upwind sources are similar. The City Center site on the downtown plateau to the west and the Maycliff site to the southeast have had lower CO values although Maycliff has approached the standard. To further define the spatial extent of high CO, two CO monitors could be installed in the area 1 to 2 km to the north and east of the E. Charleston site. The exact siting will depend on the modeling requirements and the availability of locations.

The neighborhood scale monitors distributed around the Valley are representative of several parts of the Valley and should provide satisfactory coverage for most of the valley. There are sites in the far western part of the Valley (Paul Meyer), near west/mid-Valley (Shadow Lane), near Las Vegas Strip (Flamingo), near downtown (City Center), northern part of Valley (Craig Road), lower Las Vegas Wash (Winterwood), and Southeast Valley (Pittman and Powerline). One area that appears to lack measurements is near where E. Tropicana and E. Flamingo cross the I515 freeway. Previous modeling results predicted that high CO concentrations should occur in the region along E. Flamingo Rd. from Las Vegas Blvd to I515 and south to Tropicana Ave. The western part of this region is covered by the Flamingo site, but no site has been deployed at the eastern edge of the predicted CO peak. As before, the exact siting will depend on the modeling requirements and the availability of locations.

Surface meteorological stations will be deployed near all 3 CO monitors. While the sensors will be placed on 10-meter towers as close as possible to the CO monitors, it is anticipated that towers will have to be separated by some distance to have reasonable exposure and will have to have separate data acquisition systems.

Several meteorological stations will be deployed in the Valley at elevated locations of 50 to 100 m above the ground. The location of these sites will depend greatly on the modeling requirements and site availability. It is likely that the only possible locations will be on the roofs of tall buildings, although these locations are not ideal for wind data. There are two old advertising towers near E. Charleston and downtown but they are shorter than 50 m. Deployment of sensors on an exposed roof will have to be made in such a way that the effect of air flow over and around the building exposure is minimized by elevating the sensors above the roof and away from structures.

Operating Procedures

Prior to the field study, all CO monitors and meteorological sensors will be inspected and tested for their response to calibration standards that are traceable to the National Institute of Standards and Technology (NIST). This will include zero and multipoint span checks.

Upon deployment in the field, the zero and span of each CO monitor will be adjusted using a cylinder with CO-free air for zero and a cylinder of CO in air near 45 ppm. Gas from a third cylinder with CO in air near 10 ppm will be introduced to test the linearity of the instrument and determine the so-called precision point. All comparisons of input to response will be made with the reading on the site data acquisition system.

After installation on a tower, the meteorological sensors will be checked and adjusted. The wind speed anemometer will be turned at several constant rates and the output of the DAS verified. The wind direction sensor will be aligned to measure directions relative to true north using a magnetic compass and current declination. The temperature sensor will be compared to an aspirated thermometer placed near the sensor. The relative humidity sensor will be compared to wet- and dry-bulb temperature from an aspirated psychrometer placed near the sensor.

To ensure that the instruments are operating correctly during the study, each one will be visited three times a week. One time each week, zero, span, and precision gas will be introduced to the CO monitors. There will be no adjustments to zero and span made until all three gases have been used. Then if the instrument is out of tolerance, (e.g., ±0.5 ppm for zero and ±10% for span), the zero and/or span will be adjusted and another precision point generated.

During each visit, the meteorological instruments will be visually inspected to see that they are still intact and producing reasonable data. No specific tests will be done.

Data will be collected from the DAS at each site during each visit. These data will be transmitted to Reno for review via the DRI's Internet network using File Transfer Protocol (FTP). A data analyst will review each day's data to ensure that instruments are operating correctly and that data are within expected bounds. Unusual data will be noted in anticipation of data validation.

At the end of the field measurements, zero, span, and precision gases will be introduced to each CO monitor. Wind sensors will be checked for speed response and direction. Temperature and relative humidity will be compared to the aspirated psychrometer.

A final data base containing data from the additional measurements will be developed following the completion of monitoring. During its development, all data will be reviewed in the form of plots and tabular listings and will be screened for values that exceed certain initial tolerances, such as a minimum or maximum values. The screening and plots will be used to investigate unusual occurrences. All data will be reported unless definite reasons for deletions can be found. The responses of the CO monitors to zero, span, and precision gases will be summarized. A review of the zero and span results will indicate if CO data require adjustment to remain within the uncertainties required by the model. If necessary, data will be adjusted using zero and span data. Precision data will be reported as an indicator of the repeatability of the measurements. The meteorological data will generally be reported as collected unless the final checks show that major adjustments are necessary. The final data base will contain the following hourly averages: CO concentration, scalar wind speed, unit vector wind direction, vector wind speed, vector wind direction, sigma theta (standard deviation of wind direction), temperature, and relative humidity.

Upper-Air Meteorological Data Collection

Sonoma Technology, Inc. (STI) will be responsible for deploying and operating the upper-air meteorological measurement systems to be used for this study. The meteorological conditions associated with periods of high CO concentrations in the region are generally characterized by a shallow, stable atmospheric boundary layer (ABL) in which winds are very light near the surface but stronger aloft in the upper portions of the ABL. In addition, diurnal, terrain-induced slope flows develop within the ABL. Thus, the ABL is characterized by temporal as well as vertical and horizontal gradients of winds and temperatures that control the transport and diffusion of pollutants through the region. Twice-per-day rawinsonde soundings will probably not be adequate to characterize such flows. During CO episodes, the ABL is usually at most a few hundred meters deep and often capped by a strong inversion. Rawinsonde systems are designed to provide deep profiles of meteorological parameters throughout the troposphere, so that for this study much of these supplemental data will not be useful to the modelers. (If deep tropospheric data are needed, e.g., for model initialization, the data collected twice per day at the NWS rawinsonde site at Desert Rock will be adequate for such purposes.) Clark County has correctly identified the need to collect data continuously, and the recommendation to use radar profilers reflects an understanding of the need to focus on boundary layer and lower tropospheric conditions. Thus, we have developed an approach that will provide data continuously and over the altitude range of greatest importance to the study, and still fit within the available budget.

We propose to deploy two Doppler acoustic sounders (sodars) and one 915 MHZ boundary layer radar wind profiler equipped with a radio acoustic sounding system (RASS), which measures temperature. Both instruments are manufactured by Radian International, LLC. Radian's sodars and radar profilers are remote sensing systems that are fully capable of providing the data needed for this study. They have been used on numerous air quality studies where their accuracy and reliability were an essential ingredient in the success of those studies (e.g., Lindsey et al., 1996). The sodars provide vertical profiles of wind speed and wind direction from near the surface to a few hundred meters altitude with a vertical resolution of 30 meters. The radar profiler measures winds from about 100 m agl to altitudes as high as 3-4 km, and temperatures from about 100 m agl to 1.5-2 km. The vertical resolution for both the wind and temperature profiles is 60 meters. The RASS data provide a direct measurement of the height of the mixed layer and the strength of the inversion. Both the sodar and radar profiler provide the means to look at the diurnal evolution of the ABL based on the strength of the return signals from the acoustic and radar transmissions. Both instruments operate continuously, producing profiles averaged over periods of 30-60 minutes. STI will lease two sodars from Radian, and will provide one of its own radar profilers.

A common sampling strategy used by other air quality programs with objectives similar to the Clark County study is to collocate a sodar, radar profiler, and surface-based tower system. We believe that there are more advantages in collocating a sodar and profiler than there are in establishing separate sites. Co-located instruments provide complete profiles of winds and temperature in the ABL and lower troposphere. There are other sodar technologies available that can provide data with finer vertical resolution than 30 meters, but they only sample to 100-200 meters agl, which is not high enough to meet the data objectives of this study. Also, a sodar's acoustic signals may not be able to penetrate a strong inversion, which can limit altitude coverage for a sodar. Thus, collocating a sodar and radar profiler ensures that data are recovered over the entire altitude range needed by the modelers. An added advantage to this approach is that the overlapping data provide useful quality control (QC) information to help scientists validate the upper-air data and determine how well the observations met the data quality objectives (DQOs) established by the study for accuracy, precision, and completeness. Thus, we propose to follow this approach at one of the upper-air sites, and to collocate a sodar and surface meteorological tower at the other two sites (these would also be two of the three supplemental CO monitoring sites

STI will be responsible for selecting and leasing sites suitable for sodar and profiler sampling and for preparing the sites for routine operations (e.g., shelter, power, telephone, security). They will prepare all quality assurance (QA) materials such as standard operating procedures (SOPs), forms, data logs, etc. STI has already developed these materials for other projects, so that only a modest effort will be needed to adapt them to the specific needs of this project. STI will also arrange for a field technician to be available to routinely service the sites and to provide any emergency maintenance that might be needed. We will install and test the equipment prior to the start of the sixty-day sampling period, and establish final sampling protocols at that time. STI will operate the sites for sixty days.

STI will poll each site at least once per day from its Weather Operations and Forecasting Center (WOFC), which has been set-up to operate networks of upper-air and surface stations located in different parts of the country for air quality studies like the Clark County project. STI will download the previous day's and current day's upper-air and surface data, perform quantitative screening of the observations using software developed by STI, prepare time-height cross-section plots of the data, and review the data for reasonableness. STI already has software that executes all these steps automatically, so that minimal time is needed by a data technician to review the data. While this does not take a lot of effort, a daily review of the data is an extremely important step to ensure that all equipment is working properly and that the data are reliable and are meeting the DQOs established for the study. Our experience has shown us that detecting and correcting any problems as soon as possible is one of the keys to success for upper-air monitoring projects like the one we are proposing for the Clark County CO study. The WOFC will also be used to acquire supporting data that will help us evaluate the status of our sites, such as upper-air observations collected by the National Weather Service (NWS) rawinsonde station that is operated west of Las Vegas. On-site and off-site backups of all data will be maintained.

Once the field study is completed, STI will perform Level 1 QC validation of the data that were collected on episode days that are selected for further study. Level 1 validation means that the data are subjected to quantitative and qualitative review by STI meteorologists, who are thoroughly familiar with the measurement systems used and the meteorological conditions expected to be revealed in the data. During Level 1 validation, we will identify any outliers in the data (e.g., caused by ground clutter or precipitation interference), remove erroneous data from the data sets, incorporate any changes into the data sets based on the audit findings, and assign final quality control codes to the data before they are used in modeling analyses. Once the Level 1 review is completed, STI will deliver the data sets to the project's data manager. STI scientists are the authors of new guidelines prepared for the U.S. EPA on the quality assurance, quality control, and management of upper-air data (Lindsey et al., 1995), and we will follow those guidelines as we conduct this project.

6 PHASE II UAM APPLICATIONS

DEVELOPMENT OF 1996/97 EPISODE BASE CASE

Data from the extra sites deployed during the Phase II field study will be incorporated with data collected by the APCD during the same period for use in an episode selection process and generation of UAM input files. Since the APCD data collection procedures follow EPA guidelines similar to those used to collect the enhanced data, the two sets should be compatible within the tolerances required. The reported data will include hourly averaged wind speed, wind direction, temperature, atmospheric stability, and CO concentrations. If possible, data at higher time resolution will be retained for the use of adding a stochastic component to the UAM input wind fields, as is planned in Phase I.

Development of a Phase II set of UAM input files will proceed following procedures discussed in Section 2 of this protocol, with the exception that Phase II will use the expanded database during one or more episodes selected from the 1996-97 winter CO intensive monitoring study. A full data quality assurance procedure and model diagnostic analysis will be undertaken for the CO modeling episode(s) selected from the Phase II episodes. All tests and analyses described in Section 3 for Phase I UAM modeling will be performed for the new episode(s), including an assessment of all potential model improvements described therein.

Phase II emissions modeling will be completed in the same manner as Phase I. The methodology of Phase I emissions modeling is presented in Section 2 of this protocol. For Phase II, projection of area source and point source activity, if necessary, will be completed using one of two EPA approved models for activity projection (BEAFAC or E-GAS). On-road mobile source VMT projections will be provided by the RTC. A brief description of BEAFAC and E-GAS are provided below.

FUTURE YEAR MODELING

As will be done for the base case modeling of the 1995/96 and 1996/97 winter season episodes, the future year emissions inventories will be developed following EPA emission inventory preparatory guidelines. These guidelines cover the estimation and projection of emissions as well as the procedures for developing emissions for UAM modeling applications. The EPA guidelines are contained in the following documents.

Emission Inventory Requirements for Carbon Monoxide State Implementation Plans (EPA, 1991a)

Procedures for the Preparation of Emission Inventories for Carbon Monoxide and the Precursors of Ozone, Volume I (EPA, 1991b)

Procedures for Preparing Emissions Projections (EPA, 1991c)

Procedures for the Preparation of Emission Inventories for Carbon Monoxide and the Precursors of Ozone, Volume II: Emission Inventory Requirements for Photochemical Air Quality Simulation Models (EPA, 1992a)

Procedures for the Preparation of Emission Inventories, Volume IV: Mobile Sources (EPA, 1992b)

Additional guidelines governing the estimation of future-year emissions and controls are also contained in the following documentation.

Regional Oxidant Modeling of the 1990 Clean Air Act Amendments: Default Projection and Control Data (Pechan, 1994)

Guidance for Growth Factors, Projections, and Control Strategies for the 15 Percent Rate-of-Progress Plans (EPA, 1992e)

Guidance on Projection of Nonroad Inventories to Future Years (EPA, 1994a)

Future Nonroad Emission Reduction Credits for Court-Ordered Nonroad Standards (EPA, 1994b)

Future year inventories will be developed for 2000, 2005, 2010 and 2020. It is noteworthy to mention that the U.S. EPA has not required specific methodologies for the projection of activity data, but rather has issued guidance documents outlining options and preferred approaches. We will utilize one of the two EPA-approved models for the projections of activity data, BEAFAC or E-GAS. BEAFAC utilizes data from the U.S. Department of Commerce Bureau of Economic Analysis (BEA) and is a utility program to EPS2. The Economic Growth Analysis System (E-GAS) was developed by the EPA to provide agencies with a tool to estimate activity projection factors that (1) could be updated on a more regular basis than BEA data, (2) could predict activity and the non-attainment region level, and (3) could incorporate preferred economic prediction models. The latest version (Version 3.0) of E-GAS was released in August 1995 and is compatible with EPS2. BEAFAC or E-GAS will be used for the projection of point and area source categories. On-road mobile source VMT projections will be provided by the RTC.

he only UAM inputs to be modified for future year applications are the emissions and intial concentration files. The input files that define the environmental fields (wind, temperature, meteorological scalars, etc) from the 1996/97 base case applications will be used for all future year UAM simulations. The initial concentration pattern will be uniformily adjusted by linearly scaling concentrations (above a background value of 0.2 ppm) by the projected change in daily emission rates in the basin. As the boundary concentrations will be set at 0.2 ppm, no change to the boundary file will be made. CAL3QHC inputs will be developed as outlined in Section 4, but with future year estimates for emissions and traffic cycles. The UAM and CAL3QHC will be run for the future years listed above, and their results combined to analyze effectiveness of various control strategies in meeting the CO NAAQS.

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Appendix A

EPA OMS Preliminary Methodology for Modeling Off-cycle CO Emissions

2.2.19 IN-USE DRIVING BEHAVIOR EFFECTS RECORD

2.2.19.1 Description

Recent studies suggest that in-use driving contains modes which are not adequately reflected in the standard emission testing driving cycles used to develop the emission factors for MOBILE5. In particular, the maximum rate of acceleration used in standard emission tesing driving cycles is lower than the maximum rate observed in-use. Since the rate of acceleration and other driving behavior can greatly affect the emission rate of a vehicle, especially during particular modes with extra load or enrichment, there is considerable work now being done to quantify the effect that this omission is having on mobile source inventory estimates.

MOBILE5b is using the gram per mile emission difference between vehicles run on newly designed in-use emission testing cycles and the Federal Test Procedure cycle used in vehicle certification to quantify the effect of in-use driving on the basic emission rates in the MOBILE model. The new cycles increased emissions by 0.051 grams per mile for Total HC emissions (0.043 g/mi NMHC), 2.784 grams per mile for CO emissions and .083 grams per mile for NOx emissions over the emissions measured using the Federal Test Procedure cycle. This gram per mile effect is added to the exhaust emission factor.

It is assumed in MOBILE5b that correction factors to the basic emission rate would not affect the added in-use effect. As a result, I/M programs, operating modes, temperature, fuel parameters and speed do not affect the gram per mile effect of the in-use adjustment. However, it is assumed that the in-use effect would disappear at extremely low and extremely high speeds. Therefore, the in-use effect is reduced linearly between 19.6 and 2.5 miles per hour so that the effect is zero at 2.5 miles per hour. Similarly, the in-use effect is reduced linearly between 55 and 65 miles per hour such that the effect is zero at 65 miles per hour.

The in-use effect is applied equally to all model year vehicles. The in-use effect is applied to gasoline passenger cars (LDGV) and light-duty trucks (LDGT1 and LDGT2). The NOx effect of in-use driving, but not the HC or CO effect, is applied to light-duty diesel vehicles (LDDV and LDDT). Heavy-duty vehicles (HDGV and HDDV) and motorcycles are assumed to be unaffected.

It is planned that EPA rulemaking will incorporate in-use driving effects into a new certification procedure for future model year vehicles. This will have the effect of reducing the impact of in-use driving behavior on the emissions of new vehicles subject to the new certification procedure. MOBILE5b assumes that the new certification procedure will be phased in over six years beginning in 1998. The fraction of vehicles assumed subject to the new certification procedure will be 40%, 80% and 100% for intermediate standards, and 40%, 80% 100% final standards in model years 1998, 1999, 2000, 2001, 2002 and 2003 respectively. The intermediate standards are assumed to be half as effective as the final standards. The overall effectiveness of the new certification procedure phase-in, then, will be 20%, 40%, 50%, 70%, 90% and 100% in model years 1998, 1999, 2000, 2001, 2002 and 2003 respectively. The new certification procedure final standards are assumed to reduce the increase in emissions due to in-use driving by 90% for HC emissions and 75% for CO and NOx emissions.

APPENDIX A

Final Report

THE LAS VEGAS VALLEY CARBON MONOXIDE URBAN AIRSHED MODEL UPDATE PROJECT – PHASE I: INITIAL UAM APPLICATION

APPENDIX C

Section Two
The Las Vegas Valley Carbon Monoxide Urban Airshed Model Update Project – Phase II Field Data Collection

Summary Report

THE LAS VEGAS VALLEY CARBON MONOXIDE URBAN AIRSHED MODEL UPDATE PROJECT – PHASE II: FIELD DATA COLLECTION

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1.0 INTRODUCTION

The carbon monoxide monitoring and surface meteorological data collection network operated by the Air Pollution Control Division of the Clark County Health District has fairly good coverage in the Las Vegas Valley. Several stations are located in the immediate vicinity of the East Charleston monitoring site for small-scale spatial resolution of carbon monoxide. Other stations measure carbon monoxide on the neighborhood scale.

This network was enhanced by the addition of carbon monoxide monitors and meteorological measurements (surface and aloft) at several locations. The type of measurements and deployment of equipment and their locations were determined by the results of the model evaluation in Phase I.

This report documents the measurement protocols used in the Field Data Collection task in Phase II of the Las Vegas Valley Carbon Monoxide Urban Airshed Modeling Project.

1.1 Background

The Las Vegas Valley is currently designated as a moderate non-attainment area for carbon monoxide (CO) where ambient concentrations of CO exceed the National Ambient Air Quality Standards (NAAQS) of nine ppm for an eight-hour average. The Air Pollution Control Division (APCD) of the Clark County Health District (CCHD) has measured the highest CO concentrations and the only NAAQS exceedances at the East Charleston monitoring site, located two miles east-southeast of downtown Las Vegas. A study by Bowen and Egami (1994) has shown that the ambient CO levels are nearly uniform within about half a mile of this site. Routine CO monitoring stations operated by APCD at other locations in the Las Vegas Valley have lower CO concentrations. The NAAQS have not been exceeded at any of these other monitoring sites.

Mobile sources contribute the vast majority of the total amount of CO emitted in the Valley. Estimates attribute as much as 90% of the CO to on- and off-road mobile sources (Clark County Department of Comprehensive Planning, 1995). These emissions are distributed throughout the Valley, although they are highest along freeways and major arterial streets.

The highest CO concentrations occur during winter months when longer nighttime periods result in more hours of stable atmospheric conditions that limit the dispersion of CO. In the winter, the atmosphere is likely to be stable or to be in transition to stable during the periods of highest emissions, the morning and evening rush hours. The combination of longer stable periods and low nocturnal wind speeds leads to elevated CO concentrations.

In the Las Vegas Valley as in other urban areas, the CO concentrations at all monitoring stations often reach two maxima during a 24-hour period. One peak occurs during the morning hours between about 7 and 9 AM at about the time of the morning rush hour. The other peak occurs during the late evening to early morning hours. Concentrations begin to increase near sunset during the evening rush hour and reach maximum values between 8 PM and 1 AM. The delayed evening peak of CO suggests that a combination of meteorological, topographical, and emission factors control the amount of CO measured at a particular site on a particular day and that these factors combine in such a way as to result in the highest CO concentrations occurring in the vicinity of the East Charleston site.

1.2 Objectives

The objectives of this study were:

To acquire a data base of CO and meteorological measurements with specified precision, accuracy and validity suitable as supplement to the modeling effort.

To estimate the spatial (horizontal and vertical) and temporal distribution of CO concentrations in the Las Vegas Valley and particularly in the vicinity of the East Charleston Site.

To establish relationships between CO concentrations and meteorological variables.

1.3 Project Organization and Responsibilities

Participants in the field study included:

Clark County Department of Comprehensive Planning (Mr. Clete Kus) was the primary sponsor and lead organization of the project.

Clark County Health District (Mr. Michael Naylor) was a sponsor of the project and operated the routine ambient monitoring network.

Environ (Mr. David Souten) was the prime contractor and was responsible for overseeing the efforts of the project.

Sonoma Technology, Inc. (Dr. Paul Roberts) was responsible for installing and operating two upper air meteorological sites.

Desert Research Institute (Mr. Richard Egami) was responsible for installing and operating 20 portable CO samplers and seven meteorological stations.

2.0 CARBON MONOXIDE IN THE LAS VEGAS VALLEY

The Las Vegas Valley, comprising approximately 1,500 square kilometers (km), slopes from the northwest to the Southeast. Figure 2-1 shows the CO non-attainment area which includes the cities of Las Vegas, North Las Vegas, and Henderson. The Las Vegas Valley extends along a northwest to southeast axis with the Pintwater, Desert, Sheep, and Las Vegas Ranges to the north; the McCullough Range and the Big Spring Range to the south; the Spring Mountains to the west; Frenchman and Sunrise Mountains to the east; and Lake Mead just beyond the southeastern end of the valley. The upper boundaries of the alluvial apron occur at approximately 1,400 meters (m) and are marked by a noticeable change in slope. The lower boundary of the alluvial apron is not as well defined due to massive sedimentation on the valley floor; it occurs at an average elevation of approximately 760 m. The lowland levels of the Las Vegas Valley range from 550 to 760 m (Clark County Health District, 1993).

The Las Vegas Valley is the fastest growing area in the United States. Its population increased from 125,000 in 1960 to over 1,000,000 in 1995 (Judson, 1996). Major industries and areas of employment include tourism, gaming, government/defense, chemical manufacturing, quarry operations, and construction. The major highways and streets accommodate approximately 24 million vehicle kilometers traveled on a typical weekday.

Excessive CO concentrations result from a combination of emissions, transport, meteorology and terrain. The following subsections describe these processes and evaluate the causes of elevated CO.

2.1 CO Emissions

The estimated CO emissions for the Las Vegas Valley are listed in Table 2-1. These emissions values were obtained from the Clark County Department of Comprehensive Planning and represent the winter season when high CO concentrations occur.

2.2 Meteorology of Las Vegas Valley during CO Episodes

The typical seasonal and diurnal variations of CO concentration in the Las Vegas Valley are similar to those in many urban areas (Bowen and Egami, 1994; Bowen *et al.*, 1996). Concentrations approaching or exceeding the Ambient Air Quality Standards generally occur during late Fall to early Spring (November through February). During most daily cycles, CO concentrations are low during daylight hours and have two maximum values, one in the evening after sunset and one in the morning before sunrise. During daylight hours, air near the ground has enough vertical mixing to dilute the emissions so that CO concentrations remain low. As sunset approaches, the ground begins to cool, a shallow ground-based inversion forms, and CO concentrations begin to increase. The increase continues through the evening hours, reaching maximum hourly CO values between 9 PM and 1 AM. During this time, emissions from mobile sources gradually decrease from a peak amount during the evening rush period at and shortly after sundown to a fifth that amount at midnight and to a tenth that amount at 4 AM.

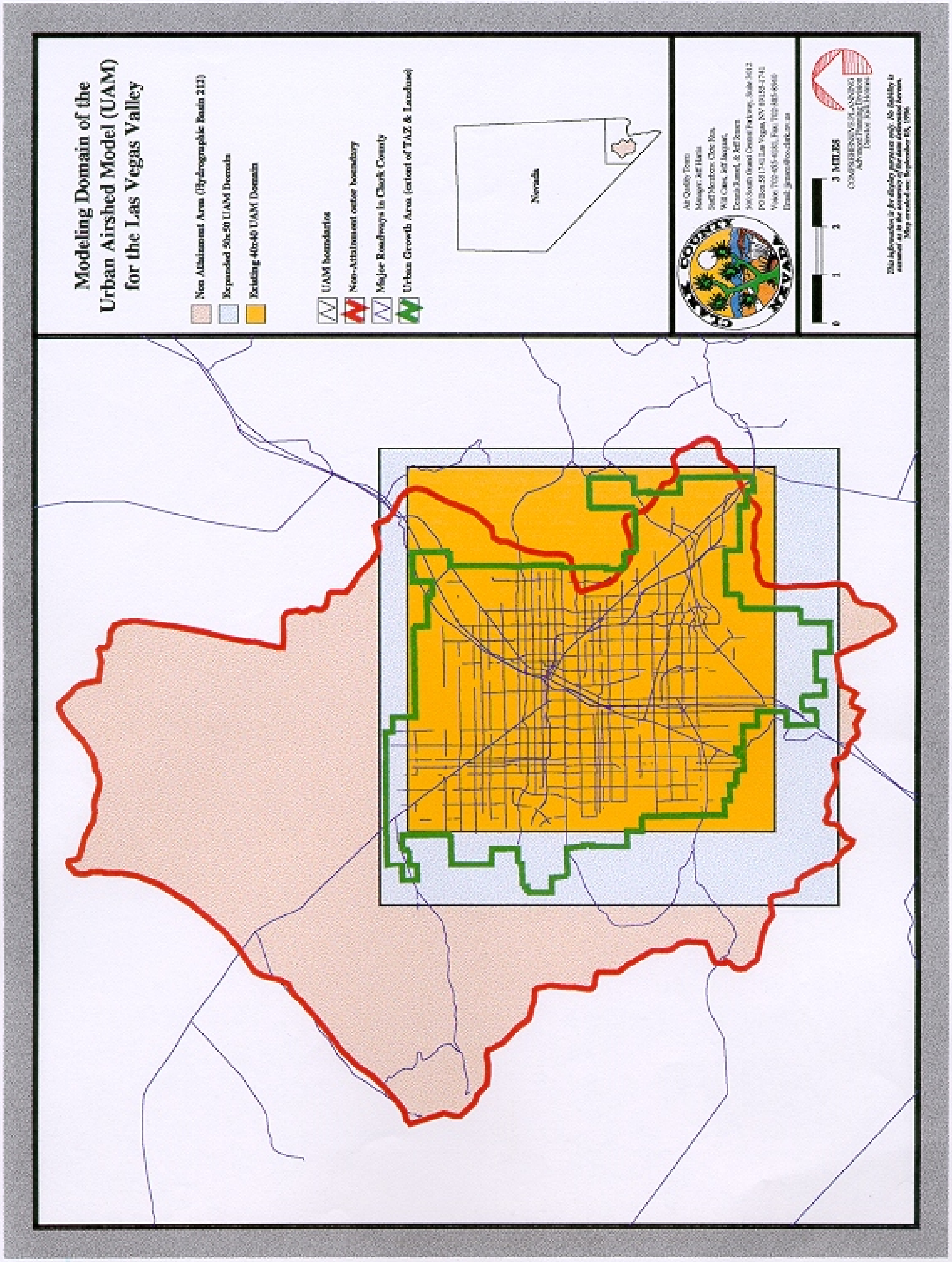
Modeling Domain of the
Urban Airshed Model (UAM)
for the Las Vegas Valley
Non Attainment Area (Hydrographic Basin 212)
Expanded 50x50 UAM Domain
Existing 40x40 UAM Domain
UAM boundaries
Non-Attainment outer boundary
Major Roadways in Clark County
Urban Growth Area (extent of TAZ & Landuse)
Nevada
3 MILES

Figure 2-1. Las Vegas Valley and CO non-attainment area.

Table 2-1. Peak Season Carbon Monoxide Emissions by Source Category[a].

Source	CO Emissions (Tons/day)	% Total
MOBILE		
On Road	303.2	89.6
Off -Road	21.2	6.3
STATIONARY SOURCES	5.5	1.6
Industrial & Commercial (includes areas outside Valley)		
Construction Activities		
Gasoline Stations		
AREA	8.5	2.5
Residential Heating		
Fireplaces		
Consumer Products		
TOTAL	338.4	100

[a] Clark County Department of Comprehensive Planning (1995).

After reaching a maximum, CO concentrations decrease during the early morning hours to a minimum at about 4 AM. Concentrations start to increase again as the morning rush hour begins with a morning maximum occurring between 7 AM and 9 AM. Shortly after sunrise, as the sun begins to heat the ground, the surface-based inversion lifts, the air near the ground begins to mix, and CO concentrations decrease by dilution.

The magnitude and daily persistence of the CO maxima depend on meteorological conditions in the Las Vegas Valley. Prolonged high CO episodes lasting several days occur during periods when a ridge of high pressure becomes situated and remains stationary over the southwestern U.S. The ridge results in weak winds aloft and at the surface and a general subsidence throughout the area. Daytime and nighttime winds at the surface are controlled by heating and cooling at the surface and local terrain. High CO concentrations can also occur for shorter periods, such as one day or one evening, when air motions near the ground become decoupled from those aloft. In either case, a surface-based inversion forms near sunset and vertical mixing is suppressed. Air motions near the ground are greatly influenced by the terrain. Nocturnal air motions tend to be downslope, with their speeds depending on the steepness and consistency of the slope.

The East Charleston monitoring station is in an area of relatively flat terrain with a gradual downward slope toward the east of about 1:100. This downward slope extends about four km to the lowest drainage point in the Valley, the Las Vegas Wash. The Wash itself lies along a

NNW to SSE line and eventually drains into Lake Mead. The slope of the Wash is about 1:150 downward toward the SSE in the area to the east of downtown Las Vegas.

Toward the west from the East Charleston site, the gradual upward slope continues for about one km. For the next 0.5 km, the terrain rises more rapidly with a maximum slope of about 1:10. The terrain flattens again in the vicinity of downtown Las Vegas with a gradual rise toward the west with slope ranging from 1:40 to 1:80 for most of the distance to the Spring Mountains, the western boundary of the Valley, some 20 km from mid-valley. The relatively-steeply-sloping topographic feature between the East Charleston site and downtown extends for some 10 to 15 km along a generally NNW to SSE line separating the Wash area from the higher surrounding terrain.

During conditions conducive to moderate to high CO concentrations, winds in the vicinity of the East Charleston monitoring site are light and variable during most of the nighttime. Shortly after sundown, a surface-based inversion forms as the ground cools. One to two hours following sunset, the wind speeds decrease to values less than one m/s for hourly averages. The low wind speed is often confined to a layer within 50 m of the surface with increases up to two to five m/s at 100 m and above. The wind directions near the surface, while generally variable, have a slight tendency to be westerly or northwesterly (i.e., downslope). Light downslope winds persist until about 8 AM or 9 AM, after which the speeds increase and the directions tend to be easterly or upslope if high pressure dominates the region.

On the western side of the Las Vegas Valley, daytime winds in the Valley are easterly to southeasterly with moderate speeds of several m/s. Within an hour after sunset, the winds become very organized into a persistent westerly downslope flow with speeds from one to four m/s. This downslope flow continues throughout the night until sunrise. The gradual downslope from the Spring Mountains to the West greatly influences the nocturnal winds in the western part of the valley. This influence appears to extend to a north-south line located somewhere to the west of the steeply-sloping terrain line.

In the downtown area on the plateau above the Las Vegas Wash, the winds show a similar diurnal variation as those at the East Charleston site. There are daytime easterly winds of several m/s. The nighttime winds are light and variable with a tendency toward westerly directions. The speeds are slightly greater than those at East Charleston, less than half a m/s difference. The low nocturnal wind speeds in the downtown area show some of the complexities of air motions in the Valley. It might be expected that winds there should be more influenced by the nocturnal downslope winds seen a few km to the west of that area. There is some evidence of moderate downslope air motions along East Charleston Boulevard between Maryland Parkway and Eastern Avenue.

At other locations in the Las Vegas Wash area, wind speeds generally exceed those at the East Charleston site by a half to one m/s. The directions are more influenced by the local terrain with distinct downslope flows being prevalent at night. To the east of the Wash, the nocturnal winds have a distinct northerly and easterly directions at speeds of about 1 m/s or greater as result of downslope drainage winds.

In summary, the meteorology of the Las Vegas Valley during episodes of high CO causes large differences in wind speed and direction depending on location and time of day. Near the East Charleston site, winds at the ground have lower speeds and more variable directions than those at other sites while winds aloft generally increase in speed and have more definite direction within the first 50 to 100 m.

2.3 Current CO and Meteorological Network

The current air quality and meteorological network operated by Clark County Health District is shown in Table 2-2 and Figure 2-2.

Table 2-2. Air Quality and Meteorological Monitoring Network in the Las Vegas Valley.

Site Location	Start Year	End Year	Observable	Instrument Type	Available Data Meteorological	UTM East	UTM North	Elev. (m) Above Ground	Elev. (m) Above MSL	Description
Frias 10245 S. Schuster Las Vegas, NV 89118 (FRIC)	1987	1994	PM_{10} Fine (0-2.5 µm) Coarse (2.5-10 µm)	PM_{10} (SSI) Particulate Monitor (Graseby-Andersen) Dichotomous Particulate Monitor (Graseby-Andersen)		662781	3998018	1.5	716	This site is located in a rural residential area. Traffic is light. Freeway I-15 is nearby with moderate to heavy traffic.
Flamingo 210 E. Flamingo Las Vegas, NV 89110 (FLAC)	1992		PM_{10}	Beta Attenuation Monitor (Graseby-Andersen)	Temperature Wind Speed Wind Direction Relative Humidity Pressure	665385.9	3998034	3.5	615	This site is located in an urban commercial area. Traffic is heavy.
	1992	1996	O_3	Ultraviolet Absorption Ozone Analyzer (Dasibi 1003AH)						
	1991		CO	Infrared CO Analyzer (Dasibi 3003)						
Bemis (A.K.A Craig) 4701 Mitchell St. North Las Vegas, NV 89031 (BEMC)	1995		$PM_{2.5}$	Beta Attenuation Monitor (Graseby-Andersen)		671439	4012654	3.5	625	This site is located in a suburban industrial area. Traffic from nearby Craig Rd. and I-5 is moderate.
	1995		CO	Infrared CO Analyzer (Dasibi 3008)						

Table 2-2. Continued. Air Quality and Meteorological Monitoring Network in the Las Vegas Valley

Site Location	Start Year	End Year	Observable	Instrument Type	Available Data Meteorological	UTM East	UTM North	Elev. (m) Above Ground	Elev. (m) Above MSL	Description
	1992		PM_{10}	Beta Attenuation Monitor (Graseby-Andersen)	Temperature Wind Speed Wind Direction Relative Humidity Pressure					
	1991		NO_x/NH_3	Chemiluminescent NO_x Analyzer (Monitor Labs 8840)						
	1991		O_3	Ultraviolet Absorption Ozone Analyzer (Dasibi 1003H)						
McDaniel Post Office 1414 E. Lake Mead Blvd. North Las Vegas, NV 89115 (MPOC)	1985		PM_{10}	PM_{10} (SSI) Particulate Monitor (Wedding & Associates)		668717	4007135	7	588	This site is located in a suburban commercial area. Traffic is heavy.
East Lake Mead 1600B E. Lake Mead Blvd., North Las Vegas, NV 89115	1996		$PM_{2.5}$	Beta Attenuation Monitor (Graseby-Andersen)		668791	4007136	5	581	This site is located in a suburban commercial area. Traffic is moderate.
	1995		PM_{10}	Beta Attenuation Monitor (Graseby-Andersen)	Temperature Wind Speed Wind Direction					
MGM	1996		CO	Infrared CO Analyzer (Dasibi 3008)						
Sunrise Acres 2501 S. Sunrise Ave. Las Vegas, NV	1996		CO	Infrared CO Analyzer (Dasibi 3008)	Temperature Wind Speed Wind Direction					
Crestwood 1300 Pauline Way Las Vegas, NV	1996		CO	Infrared CO Analyzer (Dasibi 3008)	Temperature Wind Speed Wind Direction					

Bonanza 215 E. Bonanza Las Vegas, NV 89101 (CCEC)	1989	1995	PM_{10}	PM_{10} (SSI) Particulate Monitor (Wedding & Associates)		667440	4004817	7	616	This site is located in an urban commercial area. Nearby traffic is heavy and Freeway I-95 is nearby.
City Center 559 N. 7th St. Las Vegas, NV 89101 (CCWC)	1993		PM_{10}	Beta Attenuation Monitor (Graseby-Andersen)	Temperature Wind Speed Wind Direction	656383	4.0e+07	3.5	616	This site is located in an urban commercial area. Nearby traffic is heavy and Freeway I-95 is nearby.
	1987		CO	Infrared CO Analyzer (Dasibi 3008)						
	1987	1994	NO_2	Chemiluminescent NO_x Analyzer (Monitor Labs 8840)						
	1987		O_3	Ozone Analyzer (Environics)						
East Sahara 4001 Sahara Ave. Las Vegas, NV 89104 (MAYC)	1993		SO_2	Fluorescence (CSI SA700)		672246	4001458	3.5	516	This site is located in an urban residential/commercial area. Traffic is moderate to heavy.
	1991		PM_{10}	Beta Attenuation Monitor (Graseby-Andersen)	Temperature Relative Humidity Wind Speed Wind Direction					
	1989		CO	Infrared CO Analyzer (Dasibi 3008)						
Wengert 2001 Winterwood Blvd. Las Vegas, NV 89122 (WENC)	1987	1995	PM_{10}	PM_{10} (SSI) Particulate Monitor (Graseby-Andersen)		674819	4002068	5	524	This site is located in a suburban residential area. Traffic is moderate to light with heavy traffic on Nellis Blvd.

Burkholder 335 W. Van Wagenen Henderson, NV 89015 (BURC)	1988	1994	PM_{10}	PM_{10} (SSI) Particulate Monitor (Wedding & Associates)		667200	3989000	4	579	This site is located in a suburban residential area of Henderson. Traffic is light to moderate.
Henderson 545 W. Lake Mead Dr. Henderson, NV 89015 (POWC)	1990		PM_{10}	Beta Attenuation Monitor (Graseby-Andersen)	Temperature Wind Speed Wind Direction	681200	398800	3.5	570	This site is located in an urban residential/commercial area. Traffic is moderate.
	1989		CO	Infrared CO Analyzer (Dasibi 3008)						
	1980		O_3	Ultraviolet Ozone Analyzer (Dasibi 1003H)						
	1980		NO_x/NH_3	Chemiluminescent NO_x Analyzer (Monitor Labs 8840)						
Kerr McGee 8000 W. Lake Mead Henderson, NV (KMGC)	1982	1994	NO_x/NH_3	Chemiluminescent NO_x Analyzer (Monitor Labs 8840)	Temperature Wind Speed Wind Direction	680129	3990233	NA	560	This site is located in a suburban/commercial area. Traffic is moderate.
Apex	1996		O_3	Photometric Analyzer (API Model 400)						
	1996		SO_2	Fluorescence (Monitor Labs 9850)						
	1996		NO_x/NO	Chemiluminescence NO_x (CSI 1600)						
	1996		PM_{10}	Beta Attenuation Monitor (Graseby-Andersen)						
	1996		$PM_{2.5}$	Beta Attenuation Monitor (Graseby-Andersen)						
Health District 625 Shadow Ln. Las Vegas, NV 89106 (CHDC)	1989		CO	Infrared CO Analyzer (Dasibi 3008)	Temperature Wind Speed Wind Direction	665304	4003473	6.5	590	This site is located in a suburban residential area. Traffic is light. CCHD office building.

	1989		O_3	Photometric Analyzer (API Model 1400)						
Pittman 1137 N. Boulder Wy. Las Vegas, NV 89015 (PITC)	1996		SO_2	Fluorescence (Monitor Labs 8840)		680390	3991640	4.5		This site is located in a commercial storage area. Traffic is light.
	1994		PM_{10}	Beta Attenuation Monitor (Graseby-Andersen)	Temperature Relative Humidity Wind Speed Wind Direction					
	1994		NO_x/NH_3	Chemiluminescent NO_x Analyzer (Monitor Labs 8840)						
	1994		CO	Infrared CO Analyzer (Dasibi 3008)						
	1994		Cl_2	M.S.A.						
Microscale E.I. 2801 E. Charleston Las Vegas, NV 89104 (MICC)	1995		$PM_{2.5}$	Beta Attenuation Monitor (Graseby-Andersen)		669948	4002997	4	567	This site is located in a suburban commercial area. Traffic is heavy.
	1994		PM_{10}	Beta Attenuation Monitor (Graseby-Andersen)						
	1994	1996	CO	Infrared CO Analyzer (Dasibi 3008)						
McMillan 7000 Walt Lott Dr. Las Vegas, NV	1993	1995	PM_{10}	PM_{10} (SSI) Particulate Monitor (Wedding & Associates)		657666	4006537	5		This site is located in a suburban commercial/ residential area. Traffic is moderate.
Diskin 4200 Ravenwood Drive Las Vegas, NV 89117	1993	1994	PM_{10}	PM_{10} (SSI) Particulate Monitor (Wedding & Associates)		657830	3997516	5		This site is located in a suburban commercial/ residential area. Traffic is moderate.
Dime III 2908 Gavilan Lane Las Vegas, NV 89122	1993		NO_x/NH_3	Chemiluminescent NO_x Analyzer (Monitor Labs 8840)	Temperature Wind Speed Wind Direction	675429	4000654			

	1993	H_2S	Fluorescence (Monitor Labs 9850, Thermocon Conversion)					
East Charleston 2850 East Charleston Las Vegas, 89104	1989	CO	Ultraviolet CO Analyzer (Dasibi 3008)		670092	4003036	564	This site is located in a suburban commercial area. Traffic is heavy.
	1989	NO_x/NO	Chemiluminescent NO_x Analyzer	Temperature Wind Speed Wind Direction				0
McDaniel 1600 Lake Mead Blvd. Las Vegas, NV 89115	1995	$PM_{2.5}$	Beta Attenuation Monitor (Graseby-Andersen)		668832	400721	580	
	1994	PM_{10}	Beta Attenuation Monitor (Graseby-Andersen)	Temperature Wind Speed Wind Direction				
Paul Meyer Park 4525 New Forest Dr. Las Vegas, NV 89117	1995	CO	Infrared CO Analyzer (Dasibi 5003)		657191	3997118		
	1994	PM_{10}	Beta Attenuation Monitor (Graseby-Andersen)	Temperature Wind Speed Wind Direction ΔT				
Walter Johnson 7701 Ducharme Ave. Las Vegas, NV	1995	PM_{10}	Beta Attenuation Monitor (Graseby-Andersen)	Temperature Wind Speed Wind Direction	656383	4004017	780	
Winterwood 5483 Club House Dr. Las Vegas, NV 89122	1993	H_2S	Fluorescence (Monitor Labs 9850, Thermocon Conversion)		675025	4001446	521	
	1989	CO	Infrared CO Analyzer (Dasibi 3008)	Temperature Wind Speed Wind Direction				
	1989	O_3	Ultraviolet Ozone Analyzer					

Green Valley 248 Arroyo Grande Blvd. Henderson, NV 89015	1995		$PM_{2.5}$	Beta Attenuation Monitor (Graseby-Andersen)		675025	3991294	513	
	1995		PM_{10}	Beta Attenuation Monitor (Graseby-Andersen)					
	1994		CO	Infrared CO Analyzer (Dasibi 3008)	Temperature Wind Speed Wind Direction				
Bank of America Downtown Las Vegas, NV	1994		Visibility	Transmissometer (Optical - L.P.V.)					Receiver site at Bank of America and transmitter at Sunrise Hospital.
Sunset Station Henderson, NV	1996		Visibility	Transmissometer (Optical - L.P.V.)					
Boulder City	1994		PM_{10}	Beta Attenuation Monitor (Graseby-Andersen)					
	1994		CO	Infrared CO Analyzer (Dasibi 3003)					
Variety School 2601 Sunrise Ave. Las Vegas, NV	1992	1995	CO	Infrared CO Analyzer (Dasibi 3003)	Temperature Wind Speed Wind Direction	569675	4003630		This was a temporary site for CO in winter months.
Proximity 2860 E. Charleston Las Vegas, NV	1994	1995	CO	Infrared CO Analyzer (Dasibi 3003)	Temperature Wind Speed Wind Direction Relative Humidity Solar Radiation	670092	4003036		This site was 200 ft. east of E. Charleston site.

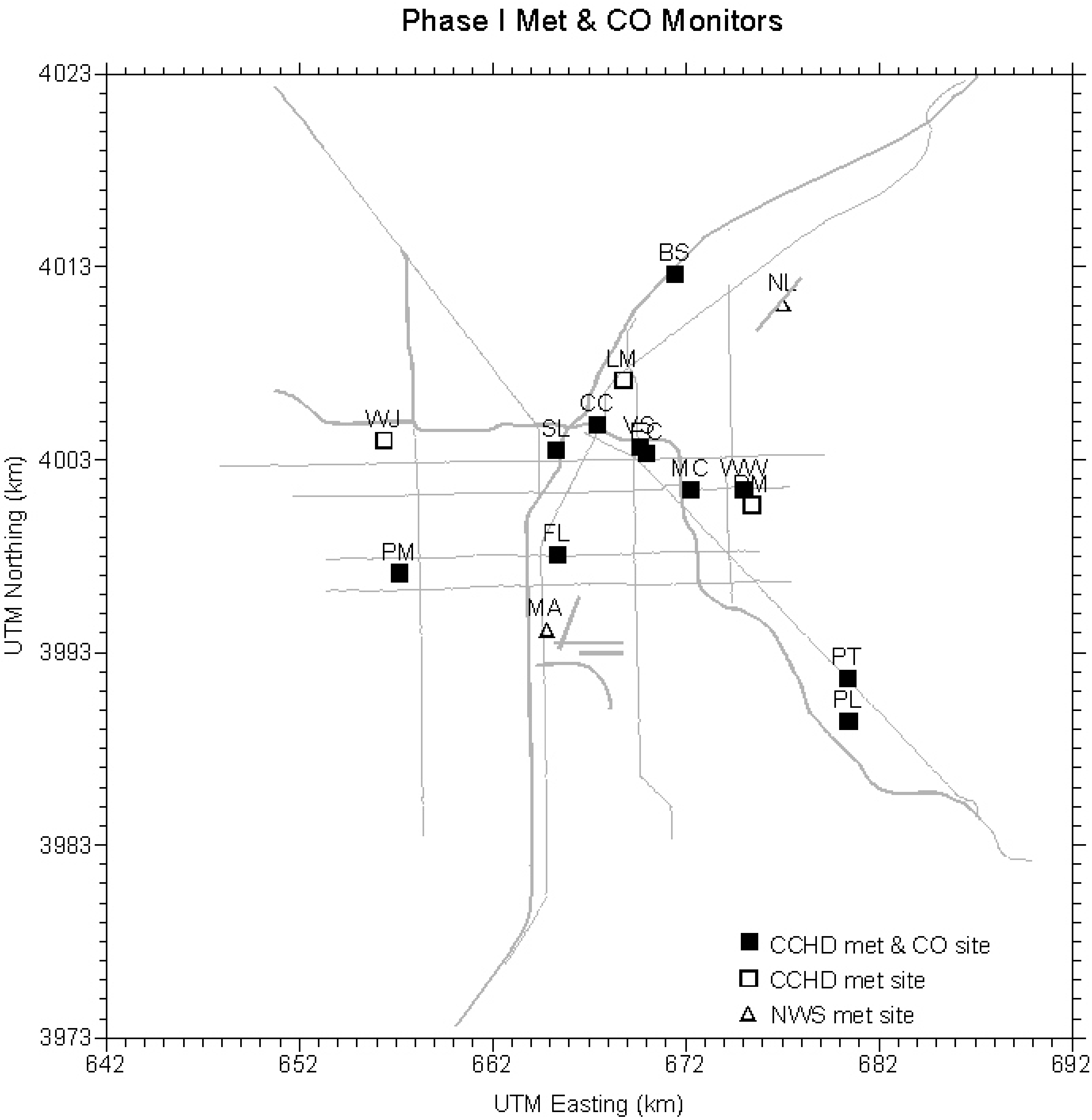

Figure 2-2. Current air quality and meteorological monitoring network operated by the Clark County Health District.

3.0 AMBIENT CO AND METEOROLOGICAL MONITORING NETWORK

3.1 Sampling Period

The originally planned study period was November 26, 1996 through January 6, 1997. A review of historical CO data had shown that the possibility for occurrences of elevated CO concentration was the highest during this period. The three holiday periods of Thanksgiving, Christmas and New Years would also have provided additional emission sources in the Valley during this period.

For much of December, the synoptic weather patterns did not provide the low wind conditions conducive to the increase of ambient CO concentrations. The field monitoring was extended to February 3, 1997 to increase the chances of obtaining data during a high CO episode.

3.2 Sampling Sites

The intent of the monitoring project was to provide ambient measurements suitable for inputs to the modeling effort. These include concentrations of carbon monoxide and surface and upper air meteorological observations. The sampling sites were designed to provide data that would be consistent with the modeling needs. Sites were placed to represent regional areas with minimal influence from specific sources.

Sites were chosen to be consistent with EPA Prevention of Significant Deterioration (PSD) (U.S. EPA, 1987) criteria as the most stringent to ensure good quality data. Sites generally had unrestricted air flow in an area of at least a 270° sector around the inlet probe. Probe height was set at 10 feet above the ground. Sites for upper air measurements were chosen to characterize the flow fields and mixing heights affecting the Las Vegas Valley area, especially during periods of high CO concentrations.

The additional CO, surface meteorology, and upper air meteorology sites are described in Table 3-1 and Figure 3-1.

3.3 Sampling Procedures

Sampling methods are summarized in this section. Detailed procedures are contained in Standard Operating Procedures (SOP) for the various measurements and in the manufacturers manual.

3.3.1 Portable CO Samplers

Ambient carbon monoxide concentrations were measured with Dräger Pac III personal gas detectors. These instruments are rugged, compact, self-contained CO detectors

Table 3-1. Portable CO, Surface Meteorological, and Upper Air Stations.
UTM Coordinates (km)

					UTM Coordinates (km)	
Site ID	Site Location	CO	Met	Upper Air	East	North
ECB 1	East Charleston	2			670.028	4003.123
MAF 2	Marnell Field	2	2		669.803	4003.776
EAB 3	Eastern and Bonanza	1			669.719	4004.635
EAO 4	Eastern and Owens	1			669.721	4006.289
BAG 5	Bruce and Grayson	1			668.604	4005.708
CAR 6	Carson and 17th	1			668.510	4003.407
CCB 7	Clark County Building			1	666.098	4003.450
CCB 22	Clark County Parking Lot	1	1		666.038	4003.309
EAT 8	Eastern and Tioga	1			669.226	3998.931
SLA 9	St. Louis and Atlantic	1			669.836	4001.811
CAP 10	Charleston and Pecos	1			671.152	4003.252
CAS 11	Charleston and Sacramento	1			672.130	4003.142
EST 12	2900 East Stewart St.		1	1	670.286	4003.758
NRB 13	North Rainbow Road		1		658.117	4013.388
PVP 14	Paradise Valley Park	1	1		670.171	3996.693
MSP 15	Marslow Park	1	1		674.090	3997.595
DRS 16	Del Robison School	1			673.511	4005.104
NFS 17	North Fire Station		1		665.304	4009.094
ARS 18	Arden Road Site		1		658.926	3986.695
CA7 19	Clark and 7th	1			667.268	4003.508
ALC 20	Alhambra and Cordova	1			667.151	4001.601
SIL 21	Silver Bowl	1			679.238	3995.384
SAB 23	Spectrum and Builders	1			670.799	4003.276
CA6 24	Clark and 6th	1			667.159	4003.559

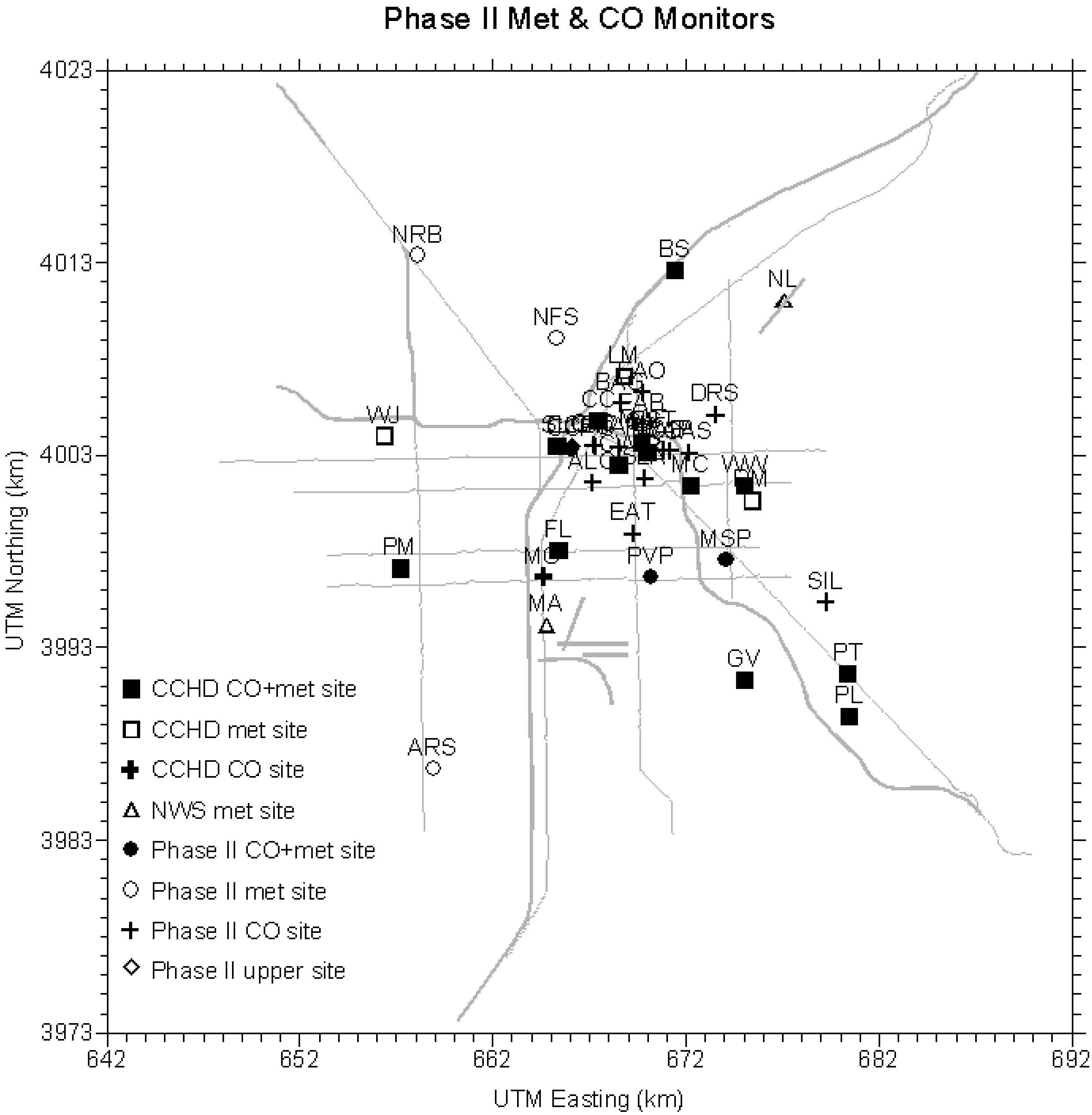

Figure 3-1 (a). Phase II meteorological and CO monitoring sites in UAM domain.

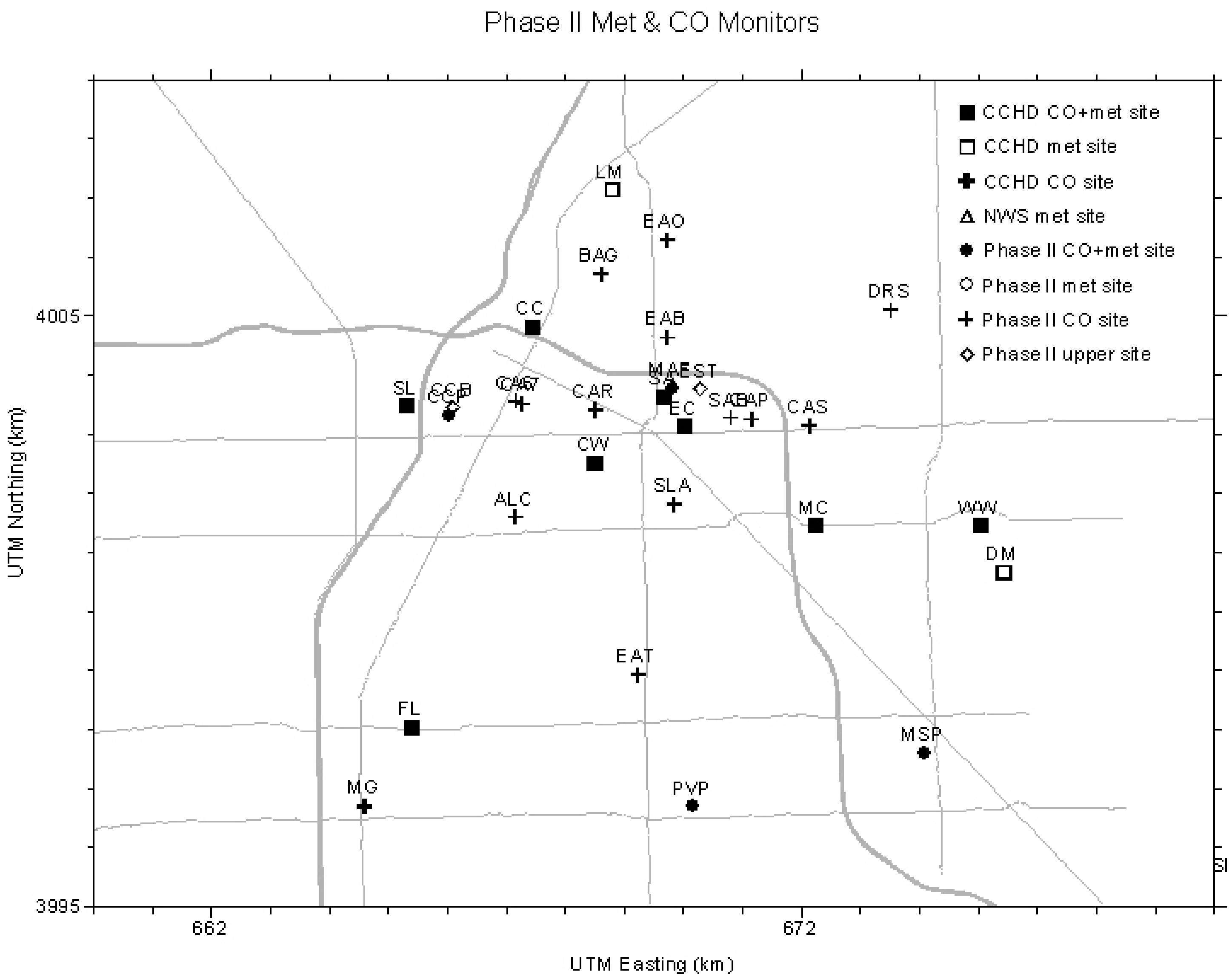

Figure 3-1 (b). Phase II meteorological and CO monitoring sites in central Las Vegas.

designed to continuously monitor CO in the ambient air. The instruments were menu-driven and logged average CO concentrations every 10 min. Data were stored in the sensors until downloaded once a week. Manufacturer's specifications are as follows:

Range:	0-2000 ppm
Resolution:	1 ppm Temperature Range: –20 to 50 °C
Battery Life:	600 hrs (Alkaline)
Size:	2.6" x 4.3" x 1.3"
Weight:	7 oz.
Averaging Time:	1 second to 15 minutes
Memory Capacity:	>1,250 hrs. for 10-minute average

3.3.2 Surface Meteorological Sensors

Surface meteorological sensors included wind speed and wind direction at all meteorological sites and temperature and relative humidity at a few sites. Instrumentation is summarized in Table 3-2.

Wind Speed

Wind speeds were measured by R.M. Young Wind Monitor-AQ (model 5305) and R.M. Young Wind Monitor-RE (model 5701). These sensors used propellers that pointed into the wind and rotated as the air passed. As the sensor rotates, the wind speeds were determined from relationships between the wind speed and the rotation rate of the sensor that were supplied by the manufacturer.

Wind Direction

Wind directions were measured by R.M. Young Wind Monitor-AQ (model 5305) and R.M. Young Wind Monitor-RE (model 5701). These sensors had vanes that oriented along the wind direction. Their orientation relative to a fixed direction, true north, was measured by a voltage across a potentiometer that was proportional to the wind direction.

Temperature

The ambient air temperature was measured with a Vaisala model HMP35C temperature/relative humidity sensor using a thermistor. The thermistor used a resistance that was inversely proportional to temperature. When a voltage was applied across the thermistor, an output current proportional to temperature was measured. The data acquisition system was programmed so as to linearize the voltage output.

Relative Humidity

The relative humidity was measured with a Vaisala model HMP35C temperature/relative humidity sensor. The sensor monitors the capacitance of a thin polymer film as it absorbs water vapor in proportion to the relative humidity.

Data Acquisition System

Continuous meteorological data were collected by Campbell Scientific Inc. Model CR10 or 21X data acquisition systems (DAS). The DAS sampled pulses or supplied excitation voltages to the sensors and sampled the signals once every second and stored these values for later processing into hourly and 15-minute averages. Temperature and relative humidity were scalar averages. The average wind variables included scalar wind speed and unit vector wind direction. The standard deviation of the wind direction, sigma theta, was computed using the Yamartino method over 15-minute segments. The hourly averaged sigma theta was computed as the root-mean-square value of the four 15-minute averages. Each record stored by the DAS was identified with a date and time. Date on the DAS was year and Julian day. These have been translated to year, month, and day in the data base. The time on the DAS was recorded at the end of an averaging period. Time in the final data base has been converted to time at the beginning of an averaging period.

Table 3-2. Meteorological Equipment at Surface Sites.

Equipment	Measurement Method	Instrumentation	Operating Range
Wind Speed (as scalar wind speed)	Propeller	RM Young Wind Monitor-AQ and -RE	0 to 50 m/s
Wind Direction (as unit vector wind direction)	Attached Vane	RM Young Wind Monitor-AQ and -RE	0 to 360°
Sigma Theta	Yamartino method	Campbell DAS	0 to 100°
Temperature	Thermistor	Vaisala HMP35C	-40 to 50 °C
Relative Humidity	Capacitive device	Vaisala HMP35C	0 to 100%
Data Logger	Digital data acquisition system	Campbell CR10 or Campbell 21X	Full range of instruments

3.3.3 Upper Air Meteorological Measurements

To support the collection of the upper-air meteorological data, one 915 MHz radar wind profiler with a Radio Acoustic Sounding System (RASS) and two Doppler acoustic sounders were used. The wind profiler system provided vertical profiles of wind and virtual temperature: 55 min. averages for winds and 5 min. averages for T_V. The acoustic sounders provided hourly averaged vertical profiles of wind. Sonoma Technology, Inc. (STI) installed and operated the equipment. To supplement the upper-air data, a 10-meter surface meteorological tower was installed at both the upper-air sites.

The sodars provided vertical profiles of wind speed and wind direction from near the surface to a few hundred meters altitude with a vertical resolution of about 75 meters. The radar profiler measured winds from about 100 m agl to altitudes as high as 3-4 km, and temperatures from about 100 m agl to 1.5-2 km. The vertical resolution for the wind profiles was 60 and 100 meters while the vertical resolution for the temperature was 60 meters. The RASS data provided data that could discern the height of the mixed layer and the strength of the nocturnal inversion. Both the sodar and radar profiler provided the means to look at the diurnal evolution of the ABL based on the strength of the return signals from the acoustic and radar transmissions. Both instruments operated continuously.

As with other air quality programs with objectives similar to that of the Clark County study a sodar, radar profiler, and surface-based tower system were collocated at one site. There are several advantages to collocating these instruments at one site. Collocated instruments provide a complete profile of the winds and temperature in the ABL and lower troposphere. Also, a sodar's acoustic signals may not have been able to penetrate a strong inversion, which would limit the altitude coverage for the sodar. Collocating a sodar and radar profiler ensured that data were recovered over the entire altitude range needed by the modelers. An added advantage was that the overlapping data provided useful quality control (QC) information to help validate the upper-air data and determine how well the observations met the data quality objectives (DQOs) established by the study for accuracy, precision, and completeness

Description of Radar Profiler/RASS

The 915-MHz boundary layer radar profiler was a pulsed Doppler radar that measured vertical profiles of wind in the boundary layer and lower troposphere. With the addition of a Radio Acoustic Sounding System (RASS), the radar profiler also measured profiles of virtual temperature (T_V). Virtual temperature is the temperature that a parcel of dry air would have if its pressure and density were equal to that of a moist air parcel. The Radian Corporation manufactured the 915-MHz Lower Atmospheric Profiler (LAP-3000) and RASS.

The 915-MHz boundary layer radar profiler was developed by researchers at the National Oceanic and Atmospheric Administration's (NOAA) Aeronomy Laboratory. The basic technology is described in Ecklund *et al.* (1990). RASS was developed in the 1970s by NOAA's Wave Propagation Laboratory and was adapted to the 915-MHz radar profiler in 1987. Radian Corporation manufactures the 915-MHz Lower Atmospheric Profiler (LAP-3000) and RASS through a Cooperative Research and Development Agreement between Radian, STI, and NOAA. This section describes the radar profiler and RASS and discusses how they operate.

The LAP-3000 consists of a single phased array antenna. The radar beam is electronically pulsed vertically and 23 degrees from vertical in any of four orthogonal directions. A "clutter fence", a rigid screen that is designed to suppress signals reflected from nearby obstacles, surrounds the antenna. The LAP-3000 includes electronic subsystems that control the radar's

transmission, reception, signal processing, and RASS. The LAP-3000 also includes a communications computer that allows users to download data and to remotely control the profiler operations. A RASS consists of four vertically pointing acoustic sources (equivalent to high-quality loudspeakers) placed around the radar antenna, and an electronics subsystem consisting of an acoustic power amplifier and signal-generating circuit boards.
The principles of profiler operation are relatively straightforward and are described in a number of references (e.g., van de Kamp, 1988). Basically, the radar transmits an electromagnetic pulse along one of the beam directions. The duration that the radar transmits determines the length of the pulse emitted by the antenna, which in turn corresponds to the volume of air illuminated (in electrical terms) by the radar beam. These radio signals are then scattered by small-scale turbulent fluctuations that induce irregularities in the radio refractive index of the atmosphere. The radar is most sensitive to scattering by turbulent eddies whose spatial scale is 1/2 the wavelength of the radar, or approximately 16 cm for a 915-MHz profiler. Signals can also be scattered by hard targets such as rain drops, trees, buildings, and birds. A receiver measures small amounts of the transmitted energy that are scattered back towards the radar (referred to as "backscattering"). These backscattered signals are received at a slightly different frequency than the transmitted signal. This difference, called the Doppler frequency shift, is directly related to the velocity of the air moving towards or away from the radar profiler along the pointing direction of the beam.

A profiler's ability to measure winds is based on the assumption that the turbulent eddies that induce scattering are carried along by the mean wind. The backscattered signals received by the profiler are many orders of magnitude smaller than the energy transmitted. However, if sufficient samples can be obtained and averaged, the atmospheric signal can be identified above the noise level and the mean velocity can be determined.

An averaged spectrum of the backscattered energy as a function of frequency is computed for each altitude, and the mean Doppler shift for each range gate is then calculated. The peak in the Doppler spectrum is identified and the zero, first, and second moments of that peak are computed. These moments represent the returned signal power, the radial velocity (the velocity of the air towards or away from the radar along the beam), and the spectral width of the peak (defined as the standard deviation of the radial velocities contained in the peak). This process is then repeated for the other beams. It takes approximately one minute to scan all beams.

The radial velocity measured by the tilted beams is the vector sum of the horizontal motion of the air towards or away from the radar and any vertical motion present in the beam. Using appropriate trigonometry, the three-dimensional meteorological velocity components (u,v,w) and wind speed and wind direction are calculated from the radial velocities with corrections for vertical motions. The LAP-3000 uses a technique referred to as "consensus averaging" to compute averaged wind profiles (Fischler and Bolles, 1981). Using this technique, the software selects the largest subset of the radial velocities measured during the averaging period that fall within a user-delectable velocity window (typically 2 m/s). At least 60 percent of the radial velocities were required to fall within 2 m/s of each other; if they did not, the winds at that altitude fail the consensus test and no wind data are reported.

For the Las Vegas CO Study, the LAP-3000 profiler was cycled between so-called “low mode” and “high mode” for measuring winds aloft. The low mode had a low-altitude coverage with a fine vertical resolution, while the high mode had a greater altitude coverage with a somewhat coarser vertical resolution. The radar profiler measured winds from about 110 m agl to 3-4 km agl with a combination of 57-m (low mode) and 100-m (high mode) vertical resolutions.

Virtual temperature is measured by RASS. The virtual temperature (T_V) of an air parcel is the temperature that a sample of dry air would have if its pressure and density were equal to those of the moist air parcel. Thus, an air parcel’s virtual temperature is always higher than its dry bulb temperature. RASS consists of four vertically-pointing acoustic sources (which are equivalent to high-quality loudspeakers) placed around the radar antenna, and an electronics subsystem consisting of an acoustic power amplifier and signal-generating circuit boards. The acoustic sources are enclosed by noise-suppression shields to minimize nuisance effects that might have bothered nearby neighbors or others working near the instrument. Each acoustic source transmits approximately 75 watts of power and produces acoustic signals in approximately the 2,020 to 2,100 Hz range.

The principle of operation behind RASS is that when the wavelength of the acoustic signal matches the half wavelength of the radar (called the Bragg match), enhanced scattering of the radar signal occurs. During RASS operation, acoustic energy transmitted into the vertical beam of the radar produces the Bragg match and allows the radar profiler to measure the speed of the acoustic signals. By knowing the speed of sound as a function of altitude, T_V profiles can be calculated with appropriate corrections for vertical air motion. As a rule of thumb, a vertical velocity of one m/s can alter a T_V observation by 1.6 °C. T_V is not being adjusted for vertical air motion since the vertical velocities tend to be noisy and potentially introduce large, unrealistic temperature variations into the data set. Any questionable T_V data are identified during the data validation process.

The profiler samples for temperature with RASS for the first five minutes of each hour. During this period, about eight RASS profiles are obtained, which are then consensus-averaged by the LAP-3000 software to produce a final, averaged T_V profile. RASS sampling is performed with a 100-m pulse length. The altitude of the first range gate varies from 110 to 124 m agl, and T_V is reported every 60 m at the center of the sampling volume. Because of atmospheric attenuation of the acoustic signals at the RASS frequencies, the maximum altitude that can be sampled is usually one to two km, depending on atmospheric conditions. High wind velocities (e.g., greater than 13 m/s) can limit RASS altitude coverage to below 500 m because the acoustic signals are blown out of the radar beam. When the five-minute RASS sampling phase was completed, the LAP-3000 sampled for winds for the remaining 55 minutes of the hour.

Doppler Acoustic Sounder (SODAR)

The sodars used for wind measurements each consisted of three antennas that were used to transmit and receive acoustic signals. The deployed system used three separate antennas pointed in three separate directions. Both the tilt angle of the beam from the vertical and the pointing direction of the antenna need to be measured when the system was set up.

The operating principle of a doppler acoustic sounder is to transmit a pulse of acoustic energy into the atmosphere, either vertically or at some angle from the vertical, and receive and interpret the acoustic backscattered signals created when the acoustic wave propagates through atmospheric turbulence. As the wave propagates upward, differences in atmospheric density cause some energy to be scattered back to the surface. This returned energy is received by the antenna and the frequency of the signal and time from transmission is determined. The difference between the transmitted and received frequencies, known as the Doppler shift, is directly proportional to the wind velocity along the beam axis. The difference in time between the transmitted and received signals, and the speed of sound, is then used to calculate the altitude from which the signal is received.
The horizontal components of the wind velocities are calculated from the radially measured Doppler shifts and the specified tilt angle from the vertical. The tilt angle, or zenith angle, is generally 14° to 30°, and the horizontal beams are typically oriented at right angles to one another. Since the Doppler shift of the radial components along the tilted beams includes the influence of both the horizontal and vertical components of the wind, a correction for the vertical velocity should be applied in systems with zenith angles less than 20°.

Operations checks, data downloading, and data quality control for the sodars were the same as for the radar wind profiler.

Data Acquisition Systems

The radar wind profiler site was equipped with two 486-based personal computers: a radar computer and a LAP-3000 Gateway computer. The POP (Profiler On-line Program) software on the radar computer controlled all aspects of sampling, signal processing, and data reduction. POP generated three data types: spectral, moments, and consensus. Spectral data contained the Doppler power spectrum for each sampling altitude and for each beam. Spectral data files were too large to be routinely archived, except for occasional diagnostic purposes. Moments data files were archived onto the radar computer's disk, and contained profiles of radial velocities, SNR, and spectral width from each 20- to 30-second scan of a beam for both wind and RASS data. Consensus data contained hourly averaged wind speeds, wind directions, and T_V data.

The LAP-3000 Gateway computer was connected to the radar computer via a local area network (LAN) and was equipped with a modem and software that allowed the user to remotely control the LAP-3000 and download data. A data formatting program running on the Gateway computer converted the raw consensus data produced by POP into the LAP-3000 common data format (CDF). Files written in the CDF had quality control codes, standard units, and descriptive information about the site. The data formatter ran hourly, a few minutes after the top of the hour, so that the most recent consensus data were always available for downloading via the Gateway software.

The sodar computer performed the same functions as both the radar and Gateway computers. A separate phone line and modem allowed daily access to the sodar data.

Parameters Measured

The radar profiler measured hourly averaged profiles of wind speed, wind direction, vertical velocity, and returned signal strength (signal-to-noise ratio). The RASS measured virtual temperature. Virtual temperature was measured for the first five minutes of each hour; winds were measured during the remaining 55 minutes.

The sodar measured hourly averaged profiles of wind speed, wind direction, and signal-to-noise ratio.

4.0 CALIBRATION PROCEDURES AND FREQUENCY

Specific calibration procedures are described in the following section. Specific instructions are contained in SOPs and in manufacturers' manuals.

4.1 Continuous CO Samplers (Dräger Pac III)

Multipoint calibrations of the continuous CO sensors were performed at the start and end of the study, following a zero and/or span adjustment necessitated by out-of-tolerance zero/span checks, and after instrument repair. Calibration gases are introduced to the analyzers at zero and up to five upscale concentrations between 10 and 90% of the effective range of the instruments (50 ppm). Instrument zero and span were adjusted for all out-of-tolerance checks except during the final check. First, the analyzer samples zero air and its zero was adjusted. Next, the analyzer samples gas concentration between 40 and 45 ppm and its span was adjusted. Then, the range of gas concentrations, including zero again, were introduced to the analyzer to obtain the multipoint span.

During the weekly site visits, zero air and several CO concentrations were introduced to the sensors from cylinders of compressed CO in air. These cylinders were obtained from Scott-Marrin Co. specifically for this project. Upscale CO concentrations were 9.81 ppm, 19.49 ppm, and 39.9 ppm. Sensors were adjusted if their response to zero air was not 0 ± 1 ppm and their response to the 39.9 ppm gas was not 40 ± 2 ppm. Concentrations for span gases were reconfirmed at DRI's Standards Laboratory in Reno.

4.2 Surface Meteorological Sensors

Meteorological sensors were checked and/or calibrated prior to deployment in the field project. Maintenance of sensors, such as bearing changes, was performed at the same time. During each site visit, the site technician visually checked that the sensors were intact. He recorded their outputs from the DAS and compared to them to estimates of the current meteorological conditions at the site.

Wind Speed

The wind speed sensors were calibrated by applying known rotation rates to the sensors while monitoring DAS readings. Variable-rate motors were attached to the anemometer in place of propeller and the sensor shaft turned at known angular speeds. DAS wind speeds were compared to the values supplied by the manufacturer of the sensor for known rotation rates.

Bearings were checked before calibration to determine if they affected the wind speed data before replacement. Rotation of shaft was checked for smoothness of operation and starting torque was measured with a torque wheel. For the R.M. Young Wind Monitors, bearings were replaced if a sensor failed to respond to a 0.3 g-cm torque.

Wind Direction

Prior to deployment, the wind direction sensors were calibrated using an angle calibrator. With the sensor in place on the calibrator and connected to the Campbell DAS, the vane was moved around the 360° circle in 10° increments. The DAS readings were compared to the calibrator angles. Sensors with readings within ±2° of the calibrator were used without correction. Sensors outside that limit were inspected for problems or used with a correction developed from the calibration.

Temperature

The temperature sensor could not be immersed in water for calibration and so was checked by placing an aspirated, NIST-traceable thermometer near the sensor and comparing the DAS and thermometer readings. The side-by-side calibration check can have an error of about ±1 °C when done outdoors because of the effect of solar radiation.

Relative Humidity

The relative humidity sensor was checked by placing an aspirated psychrometer with NIST-traceable thermometers near the sensor. As with the temperature check, the psychrometer should be shaded from direct solar radiation while being exposed to the free-air. Simultaneous readings from the sensor and the wet- and dry-bulb thermometers of the psychrometer were recorded. The relative humidity was determined from psychrometric tables or a psychrometric slide rule.

4.3 Upper Air Meteorological Sensors

There were no specific calibration procedures for the radar profiler/RASS system. Comparisons with other measurements made during several studies, most recently during summmer, 1996 at El Paso, Texas, have shown that the radar profiler/RASS system yields reasonable results.

5.0 DATA REDUCTION, VALIDATION, AND REPORTING

DRI and STI were responsible for reducing, validating, and reporting data. In this section, descriptions of data processing procedures are grouped by participant.

5.1 Continuous CO and Meteorological Data – DRI

The following describes the processing of continuous CO and meteorological data. The objective of the data reduction and validation effort is a quality assured monitoring data base in a consistent format. The procedures meet the requirements and guidelines of 40 CFR 58, Appendices A, B, and C (U.S. EPA, 1989a, 1989b, 1989c); Quality Assurance Handbook for Air Pollution Measurement Systems, Volumes I, II, and IV (U.S. EPA, 1984, 1986, 1989d).

Data Base

Prior to deployment of field equipment, a data base directory containing information specific to the project was created. The directory included site names, numbers, and locations; reporting period, status code, units, reporting precision, and outlier flags. Date of last access and modification is also provided.

Most data processing activities were conducted with the aid of a data base management system developed at DRI. A combination of manual and automatic data processing steps accomplished the following:

Outlier screening,

Data base loading of data,

Updating on-line status files,

Data base entry and editing,

Data base access and process flow control,

Data flagging,

Data calibration through application of appropriate slope and intercept,

Data base creation, and

Creation of routine data summaries.

Averaged CO and meteorological data were retrieved weekly from the field by a field technician. Data were transferred to the Reno via a file transfer protocol (FTP) connection on DRI's computer network. Data were plotted as they are received for visual review to check that instruments were operational. These data were visually screened for anomalies that would require further investigation.

All site documentation were sent from the field to DRI weekly. This included site logs, checklist logs, zero/span checks, and multipoint calibration results. Upon receipt, the ancillary site data were logged in and made available for use during data processing.

Data Processing

Continuous data received in Reno required some initial processing before validation could commence.

CO data were averaged and logged internally by the CO sensors every 10 minutes. The sensor software did not, however, provide data collection at even 10-minute intervals. Thus, the data from the individual sensors were averaged over slightly different intervals of time. In order to have data from comparable time intervals, time-weighted averages were computed for each set of two adjacent averages for all sensors with the resulting sample end time at the even 10-minute value between the two. To generate hourly averaged CO concentrations, the 10-minute time-weighted averages were averaged for each hour.

Meteorological data were collected in a comma-separated-variable (CSV) format as averages covering even 10-minute intervals. The CSV data were entered into dBase IV files. Data were retimed from a time-ending to time-beginning convention. Listings of 10-minute data were generated. The 10-minute data were averaged to obtain hourly averaged data using either scalar, vector, or root-mean-square methods, as appropriate. Lists and plots of the hourly-averaged data were generated.

Data Validation

All data were reviewed before use, starting with observations and reports from the site operators and continuing with the review of logs, checklists, and data. All flagged or anomalous data were investigated. All data were retained unless substantial evidence was available for their deletion.

For CO data, zero and span check data were reviewed as an integral part of the process. Deviations of the span values from the introduced gases were reviewed. If the span responses had deviated by more than 25% or the zero by more than 3 ppm from expected values, data would have been invalidated. This did not occur for any CO sensor. Zero and span data collected each site visit were applied to data from all sensors. Data with non-zero responses to zero-air were corrected. The average slope for each sensor was determined for each data collection period and used to adjust the collected data.

For meteorological data, the site visit logs, weekly data, and post-sampling checks were reviewed as part of the data validation. Alignment and data collection problems were identified and the collected data corrected.

All changes resulting from reviewing documentation were made directly on the raw data report and comments added as required. Raw data reports were reviewed to see that outliers have been corrected, replaced by missing data code if deleted, or checked as valid. When raw data were completely checked and corrected, changes are made to the data base and any necessary correction factors applied.

5.2 Upper Air and Surface Meteorological Data - STI

STI processed data from the two upper air sites.

Data Collection

Data from each of the STI upper air sites were downloaded on a daily basis to STI's operations by executing an automated process on the Hub computer. During this process, Gateway computers at each site were called via modem, and the previous day's data were downloaded. STI staff reviewed the data each day to verify that all data were retrieved. If the data were not received from a site, STI staff immediately called the site to determine the cause of the problem and to take corrective actions as required. The communications software on the Gateway computer at each site allowed STI staff to remotely diagnose potential problems with the profiler, change the profiler operating parameters, re-start the profiler, and re-boot either the radar or the Gateway computers. In some cases, STI summoned the operators to the site to perform repairs that could not be performed remotely. Once all the files were received and properly archived, their receipt was recorded on a QC log form. Problems with instruments or missing data were also noted on the log form.

The site operators sent copies of the radar profiler moments and consensus data and the surface wind data to STI approximately every week. Receipt of these data were recorded on a log form, and backup copies were made on a Colorado backup tape. A copy of the data sent to STI by the site operators was stored in STI's operations center, with a backup copy stored offsite.

Data Processing and Quality Control

Once the radar profiler data files were stored on the Hub computer, they were automatically subjected to quality control screening software and plotted. Plots of the radar profiler wind and the RASS virtual temperature data were reviewed daily for any problems.

If any problems were encountered, corrective actions were initiated as quickly as possible. The data validation process involved identifying physically, spatially, or temporally inconsistent observations ("outliers"), and assigning QC codes to each data point to indicate its validity. There were several stages or "levels" in the data validation process:

Level 0 validation: Raw; non-QC'd data.

Level 0.5 validation: Data subjected to automatic QC screening by software.

Level 1.0 validation: Data subjected to quantitative and qualitative reviews for accuracy, completeness, and internal consistency. The qualitative reviews were performed by STI staff thoroughly familiar with the measurement systems used and the meteorological processes expected to be contained in the data. In addition, changes to data required based on results of audits were incorporated into data sets.

The overall objective of the data validation process for this study was to produce a database of observations at Level 1.0 validation for specific episode days. Level 1.0 validation meant that erroneous data (e.g., winds contaminated by ground clutter) were removed from the data base, and that questionable data were identified for users via QC codes. Table 5-1 defines the QC codes for data base for the Level 1.0 radar profiler data sets. The following steps were used to bring the profiler and RASS data to the Level 1.0 validation.

The Level 0 data were downloaded daily from each site. The Hub computer then performed automated quality control screening on the data using the LAPQC program, which brought the data to Level 0.5 validation. The LAPQC program used a pattern recognition algorithm developed by NOAA (Wuertz and Weber, 1989) to examine the continuity of the data in time and altitude and to identify possible data outliers. Dominant patterns were established that link consistent data in time and altitude. Then data that vary from neighboring values by more than user-specified thresholds were flagged as suspect by the software. In addition, the LAPQC program produced a log of all data identified as questionable.

Table 5-1. Quality Control (QC) Codes used in the Radar Profiler Data Base.

QC Code	QC Code Name	Definition	Content of Data Field
0	Valid	Observations judged accurate within the performance limits of the instruments.	Data value
1	Estimated	Observations that require additional processing because the original values were suspect, invalid, or missing. Estimated data may be computed from patterns or trends in the data (e.g., via interpolation), or they may be based on the meteorological judgment of the reviewer.	Data value
7	Suspect	Observations that, in the judgment of the reviewer, are in error because their values violated reasonable physical criteria or did not exhibit reasonable consistency, but a specific cause of the problem is not identified (e.g., excessive wind shear in an adiabatic boundary layer).	Data value
8	Invalid	Observations that are judged inaccurate or in error, and the cause of the inaccuracy or error is known (e.g., winds contaminated by ground clutter or a temperature lapse rate that exceeds the autoconvective lapse rate). Besides the QC flag signifying invalid data, the data values themselves are assigned invalid indicators.[a]	–940 –950 –960 –980
9	Missing	Observations not collected (because the profiler was not operating).	-999

[a] For invalid data, indicators are used in the data field instead of a data value. They are assigned as follows:
- –940 Data are identified as invalid by the QC screening software.
- –950 Insufficient samples exist to create a consensus average.
- –960 The magnitude of the radial velocity exceeds the Nyquist velocity, which is the maximum velocity that can be unambiguously resolved (a function of the profiler's configuration).
- –980 Data are identified as invalid by the reviewer.

Backup copies of the Level 0 and 0.5 data were automatically made each night. Approximately every 2 weeks, the Level 0 and 0.5 data were archived onto a Colorado tape and stored offsite.

Next, was the manual review of the data. The reviewer carefully examined each data set, looking for outliers and evaluating the reasonableness and internal consistency of the data. The reviewer verified the results of the automated QC screening, either accepting the results or re-defining "suspect" data as either "valid" or "invalid", as appropriate. As described in the next section, the reviewer used internal and external sources of QC data to assist in determining the validity of the observations.

The reviewer changed the QC flags using the LAPG program, which allowed the reviewer to interactively select those data points that appeared inconsistent and to edit the QC flags associated with those data. A log of the QC changes was created by the program. Once the review of a data set was completed and any changes made based on the audit results, (i.e., the data were brought to Level 1.0 validation), a new copy of each data file was made and the reviewer initialed and dated the QC log form. A separate copy of the Level 1.0 data sets was made and stored at an offsite location.

Quality Control Data

To evaluate how well the upper-air data met the data quality objectives established for the study and to assist in determining the validity of questionable data during the data validation process, the profiler and RASS data were often compared to other supporting data sets. These supporting data came from both internal and external sources.

Table 5-2 lists the internal data sources that are commonly used and gives a brief explanation of their use. Internal data sources included other parameters that were measured by the same instrument, collocated data sources (i.e., surface meteorological data), and other

Table 5-2. Internal Data Sources for Data Validation of Radar Profiler and RASS Data.

Internal Data Sources	Usage
Profiler vertical velocity data	Check for precipitation contamination in the profiler wind data. Check for vertical velocity biasing in the RASS data.
Profiler signal-to-noise ratio (SNR) data	Check for precipitation contamination, bird contamination, ground clutter, and altitude coverage in the profiler data.
Surface meteorological wind data	Check for consistency in the profiler's lower-level wind data.
Surface meteorological precipitation data	Check for precipitation contamination in the profiler wind data.
Site operator logs	Check for instrument problems and corrective actions.

internally generated data produced as part of the study (e.g., instrument performance logs and site operator logs). For example, when checking for precipitation contamination in the profiler on RASS data, STI staff often relied on profiler vertical velocity data, collocated rain gauge data, synoptic weather charts, and site operator weather observations.

Table 5-3 shows a list of external data sources and gives a brief explanation of their use. External data sources included data that collected by other agencies or participants. A few examples of external data include National Weather Service (NWS) upper-air rawinsonde data and NWS upper-air and surface weather charts and satellite images. As a rule of thumb, the criteria for agreement between methods is ± 20° for wind directions and ± 5 m/s for wind speeds.

Formal procedures for documenting the use of the quality control data shown in Tables 5-2 and 5-3 during data validation are being developed.

Table 5-3. External Data Sources for Validation of Radar Profiler and RASS Data.

External Data Sources	Explanation of Usage
NWS upper-air rawinsonde soundings	Perform reasonableness checks on the upper level profiler wind and temperature data. In general, the criteria for agreement were generally considered to be ± 20° for wind direction, ± 5 m/s for the wind speed, and ± 2.3°C for T_v. If the data were outside these limits, additional steps were taken to verify their validity.
NWS upper-air meteorological charts	Perform reasonableness checks to evaluate the spatial consistency of the upper level profiler winds based on geopotential height gradients depicted on 700 mb and 850 mb charts. The same agreement criteria as above were used. If the data were outside these criteria, additional steps were taken to verify their validity.
NWS surface meteorological charts	Track synoptic scale weather features (i.e. frontal positions, thunder-storms) that may affect instrument performance on data quality.
Satellite images	Track synoptic-scale weather features (i.e. frontal positions, thunder-storms) that may affect instrument performance on data quality.

6. INTERNAL QUALITY CONTROL CHECKS

The individual participants in the field project were responsible for internal quality control for the data they collected. In this section, descriptions of quality control checks procedures are grouped by participant.

6.1 Continuous CO and Meteorological Sites - DRI

One site visit was made to each site by a local field technician each week. DRI provided training for the site technician. Zero/span checks and precision checks were performed each week. Instrument calibrations were done at the beginning and end of the study.

Site Visits

Site visits were used to ensure that all equipment were operating properly, to identify instrument problems, and to give warning of developing problems.

Station checks were performed each site visit following the steps prescribed on the station check forms.

Each site visit, the site technician visually inspected the meteorological sensors and the continuous CO samples.

All visits are documented on site visit forms and in a bound logbook. Each week, copies of recorded data and logbook pages are sent to DRI in Reno for review and processing.

Quality Control Checks

Quality control checks consisted of weekly zero/span checks and precision checks. In both cases, test atmospheres were introduced to the sensor operating in its normal sampling mode. Test gases passed through all filters, scrubbers, conditioners, and other components used during normal sampling.

Each CO sensor was subjected to a zero/span check and precision check weekly. For zero/span, test gases at zero and one span concentration were introduced to each sensor. The span gas concentration was 39.9 ppm. Zero/span data were used to determine if a sensor needed adjustment and to evaluate validity of data. No changes are made until all initial checks are complete. For precision checks, test gases at 9.8 ppm and 19.5 ppm were introduced to each sensor to test its repeatability. The following criteria were used in evaluating the data:

Zero Checks: Weekly check should have been 0 ± 1 ppm. If two consecutive zero checks exceeded this value, the instrument zero would have been adjusted. If adjustment were not possible, the sensor would have been removed from service and sent to the manufacturer for repair. If the zero exceeded ±2 ppm, the instrument would have been recalibrated immediately. If the zero exceeded ±10 ppm, the sensor had serious problems and data would have been invalidated. The sensor would have been recalibrated.

Span Checks: Weekly check (at 39.9 ppm) should have been within ±5% of cylinder value. If not, the span was adjusted. A sensor that could not be recalibrated was returned to the manufacturer for repair. If the check had exceeded ±15%, the instrument would have been consider to have had serious problems and data would have been invalidated. The span would have been adjusted if the sensor was operable.

Precision checks: Weekly checks (at 9.8 ppm and 19.5 ppm) were recorded after initial zero and span checks had been done. There were no specified limits.

The responses of the sensors to zero air and span gas were used to calculate correction factors for the CO data. In all checks except one, the responses to zero air were zero. In the one exception, the response to zero and ambient air was 7 ppm during the site visit. Over a period of several hours, the response to ambient air decreased to 0 ppm. Ambient data were acorrected to 0 ppm for this time. For each sensor, slope corrections were calculated for the period of time between site visits (approximately one week) from the average of the span responses at the beginning and end of the period. The slope corrections are given in Table 6-1.

The results of the precision checks are given in Table 6-2. The differences and percent differences between the sensor responses (corrected for slope) and the input CO concentrations were computed. The table contains the average and standard deviation of the differences and percent differences for the measurement period.

Collocated Measurements

Two CO sensors were installed at the East Charleston site to collect simultaneous measurements of CO concentrations. Differences and percent differences between the data were computed The differences and percent differences between the primary and collocated sensors are given in Table 6-3. The sensor are compared for all measurements with values grreater than 0 ppm and greater than 4 ppm. For the first case, large percent differences can occur at low concentrations even though the absolute differences are small. For concentrations greater than 4 ppm, the percent differences show less variability. For the sensors at East Charleston at the higher concentrations, the collocated sensor averaged about 0.6 ppm higher than the primary sensor with a percent difference of 9.5%. At the higher concentration, the variability in the differences was about half that at lower concentrations with standard deviations of 0.2 ppm for the differences and 5% for the percent differences.

Table 6-1. Average Slopes for Draeger CO Sensors - Las Vegas (Nov., 1996 - Feb., 1997).

Site	Sensor ID	11/22/96 to 11/26/96	11/26/96 to 12/2/96	12/2/96 to 12/9/96	12/9/96 to 12/16/96	12/16/96 to 12/23/96	12/23/96 to 12/30/96	12/30/96 to 1/6/97	1/6/97 to 1/13/97	1/13/97 to 1/20/97	1/20/97 to 1/27/97	1/27/9 7 to 2/3/97
ECB01_P	LV 001	1.003	1.023	1.036	1.023	1.023	1.050	0.979	1.017	1.023	1.023	0.998
ECB01_C	LV 002	1.003	0.997	0.998	1.010	1.023	1.036	0.979	1.017	1.036	1.065	1.010
MAF02_U	LU 003	1.009	1.022	1.030	1.057	1.010	1.023	1.017	1.023	1.036	1.030	1.044
MAF02_L	LV 004	0.998	1.004	1.010	1.017	1.004	1.017	1.017	1.017	1.030	1.030	1.023
EAB03	LV 005	0.987	1.006	1.017	1.017	1.017	1.017	1.017	1.010	1.023	1.017	1.010
EAO04	LV 006	0.919	1.017	1.036	1.036	1.057	0.985	0.998	1.017	1.043	1.024	1.010
BAG05	LV 007	0.998	1.017	1.043	1.057	1.004	1.023	1.057	0.998	1.004	1.017	0.998
CAR06	LV 008	1.009	1.028	1.036	1.065	1.004	1.017	1.010	1.004	0.980	0.974	1.017
CCB22	LV 009	0.998	1.017	1.030	1.023	1.023	1.030	1.065	1.017	1.023	1.010	1.010
EAT08	LV 010	1.003	0.997	1.004	1.017	1.037	1.004	1.004	0.998	1.017	1.023	1.044
SLA09	LV 011	1.021	1.040	1.057	1.010	1.030	1.031	1.031	1.057	1.010	1.010	1.017

Table 6-1. (Continued). Average Slopes for Draeger CO Sensors - Las Vegas (Nov., 1996 - Feb., 1997).

Site	Sensor ID	11/22/96 to 11/26/96	11/26/96 to 12/2/96	12/2/96 to 12/9/96	12/9/96 to 12/16/96	12/16/96 to 12/23/96	12/23/96 to 12/30/96	12/30/96 to 1/6/97	1/6/97 to 1/13/97	1/13/97 to 1/20/97	1/20/97 to 1/27/97	1/27/9 7 to 2/3/97
CAP10	LU 012	1.015	1.034	1.043								
CA623	LV 012								1.037	0.998	0.998	0.998
CAS11	LV 013	1.009	1.028	1.036	1.057	1.004	1.004	0.998	1.031	1.010	1.010	1.023
PVP14	LV 014	0.967	0.926	0.977	1.023	1.023	1.043	0.998	1.017	1.017	1.045	1.039
MSP15	LV 015	0.977										
SAB22	LV 015								0.998	1.010	1.023	1.036
DRS16	LV 016	0.998	0.998	1.004	0.974	1.010	1.023	1.011	0.991	1.017	1.017	1.010
CA719	LV 017	0.982	0.982									
SPM20	LV 018	0.998										
SIL21	LV 019	1.021	1.040	1.043	1.043	1.036	1.036	1.050	1.010	1.030	1.011	0.998
ALC20	LV 020	1.021	1.034	1.030	1.036	1.036	1.050	1.004	1.010	1.010	1.010	1.004

Table 6-2. Precision Tests for CO Sensors.

Site	Sensor ID	Input 9.8 ppm				Input 19.5 ppm			
		Difference, ppm		Difference, %		Difference, ppm		Difference, %	
		Average ppm	Std Dev	Average %	Std Dev	Average ppm	Std Dev	Average %	Std Dev
ECB01_P	LV 001	0.2	0.6	2.3	6.2	0.2	0.5	0.9	2.8
ECB01_C	LV 002	0.3	0.4	2.6	3.6	0.2	0.6	0.9	3.1
MAF02_U	LU 003	-0.3	0.5	-2.9	5.3	-0.1	0.5	-0.7	2.8
MAF02_L	LV 004	0.1	0.4	1.1	4.0	0.2	0.3	0.9	1.8
EAB03	LV 005	0.3	0.3	2.7	2.9	0.4	0.3	2.1	1.8
EAO04	LV 006	0.3	0.3	2.9	3.3	0.3	0.5	1.5	2.3
BAG05	LV 007	-0.3	0.4	-2.8	4.3	0.0	0.5	-0.2	2.5
CAR06	LV 008	0.0	0.4	-0.1	3.8	0.2	0.5	1.1	2.4
CCB22	LV 009	-0.1	0.4	-0.7	4.5	0.2	0.3	0.9	1.4
EAT08	LV 010	-0.2	0.2	-1.5	2.3	0.0	0.4	0.2	1.9
SLA09	LV 011	-0.2	0.3	-2.4	3.6	-0.3	0.3	-1.5	1.7
CAP10	LU 012	0.1	0.4	1.5	4.3	0.0	0.5	-0.1	2.5
CA623	LV 012	0.1	0.5	1.3	4.8	0.1	0.4	0.7	2.0
CAS11	LV 013	0.0	0.4	-0.4	3.8	0.0	0.3	-0.1	1.7
PVP14	LV 014	-0.5	0.5	-5.4	5.2	-0.2	0.8	-1.3	4.0
MSP15	LV 015	0.4		3.8					
SAB22	LV 015	-0.1	0.2	-1.5	1.6	0.0	0.3	-0.2	1.8
DRS16	LV 016	0.0	0.4	0.1	3.6	0.4	0.2	2.1	1.2
CA719	LV 017	-0.5	0.0	-5.0	0.1	0.1		0.7	
SPM20	LV 018	Sensor inoperable shortly after installation							
SIL21	LV 019	-0.2	0.4	-1.9	3.8	0.1	0.4	0.6	1.9
ALC20	LV 020	0.2	0.2	1.8	2.4	0.2	0.2	1.0	0.9

Table 6-3. Comparison of Primary and Collocated Sensors at East Charleston.

Period	Sensors > 0 ppm				Sensors > 4 ppm			
	Difference[a]		% Difference[b]		Difference		% Difference	
	Average	Std Dev	Average	Std Dev	Average	Std Dev	Average	Std Dev
All	0.3	0.5	33.7	39.2	0.6	0.3	9.5	5.2
November, 1996	0.2	0.4	33.0	41.6	0.4	0.4	8.1	7.6
December, 1996	0.4	0.4	32.2	38.2	0.5	0.3	8.6	4.8
January, 1997	0.3	0.5	35.1	40.3	0.6	0.3	11.1	5.1
February, 1997	0.6	0.6	41.4	38.0	0.7	0.4	13.0	6.8

[a] Difference = Collocated - Primary
[b] % Difference = 100*(Collocated-Primary)/[(Primary+Collocated)/2]

The concentrations from the CO sensors also been compared to CO concentrations measured by the CO analyzer operated by the CCHD at the site. Results of these comparisons are given in Table 6-4. Only the values with sensor concentrations greater than 4 ppm are given. At higher concentrations, the averaage values for primary and collocated sensors exceeded that of the CCHD analyzer by 0.2 and 0.7 ppm,respectively. The variability of the differences was more than that between sensors. For the primary sensor, ths standard deviations were 0.5 ppm for the differences and 8.6% for the percent difference. For the collocated sensor, the standard deviations were 0.5 for the difference and 10.5% for the percent difference.

In addition to the numerical comparisons, Figure 6-1 contains plots of the CO sensors and the CCHD analyzer at East Charleston for a short time period (January 8 through January 11, 1997). The figure shows that the sensors tracked the CCHD analyzer well at CO concentrations above 3 to 4 ppm.

Table 6-4. Comparison of Primary and Collocated Sensors to CCHD Analyzer at East Charleston.

Period	Primary Sensor > 4 ppm				Collocated Sensor > 4 ppm			
	Difference[a]		% Difference[b]		Difference		% Difference	
	Average	Std Dev	Average	Std Dev	Average	Std Dev	Average	Std Dev
All	0.2	0.5	3.5	8.6	0.7	0.5	14.4	10.5
November, 1996	0.1	0.6	3.1	11.4	0.6	0.3	13.1	7.3
December, 1996	0.3	0.5	4.6	9.0	0.7	0.5	13.5	9.3
January, 1997	0.1	0.4	1.4	7.1	0.7	0.4	15.3	12.5
February, 1997	0.3	0.2	6.5	4.6	1.0	0.4	23.8	7.9

[a] Difference = Sensor - CCHD analyzer
[b] % Difference = 100*(Sensor-CCHD analyzer)/(CCHD analyzer)

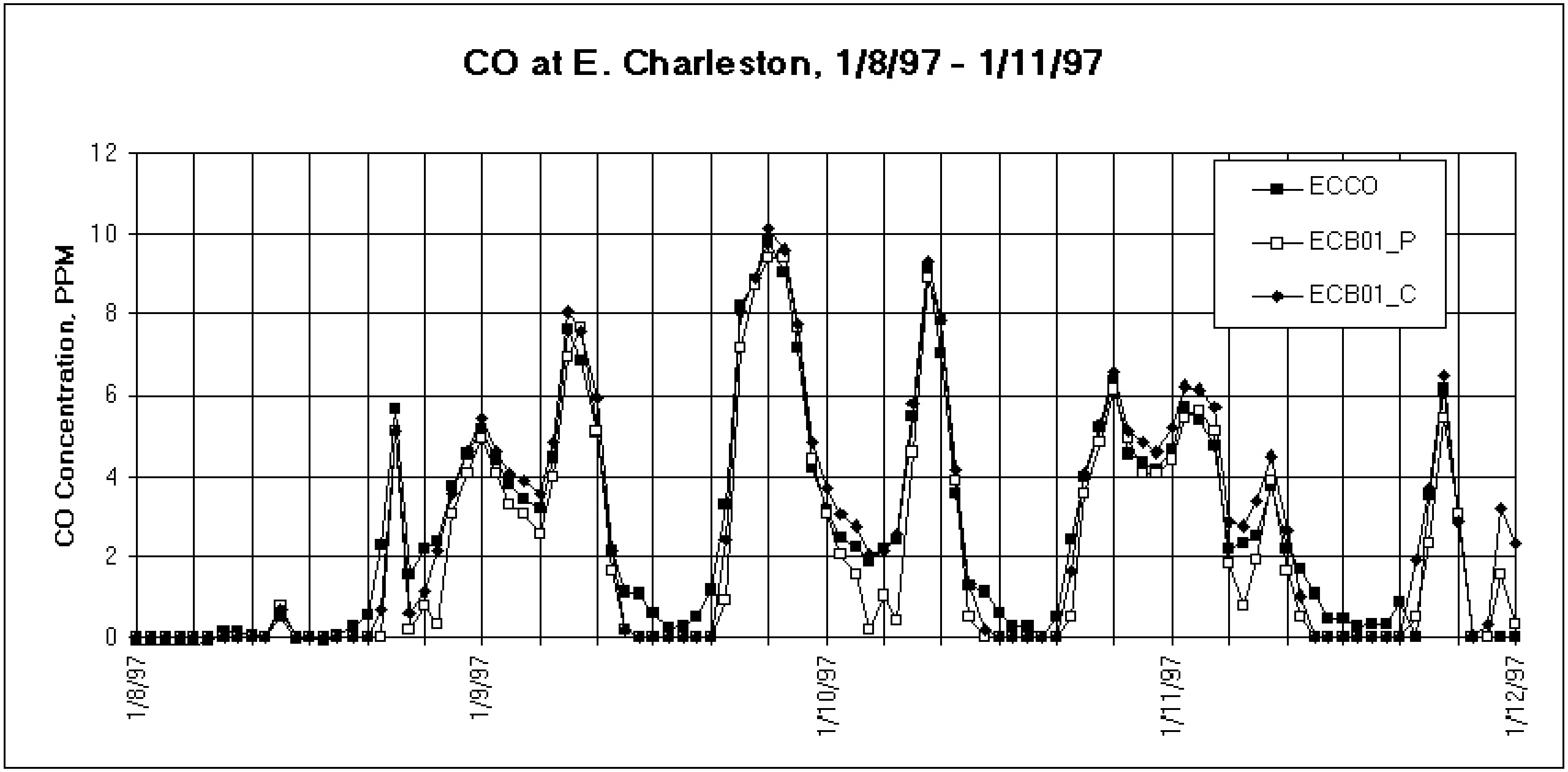

Figure 6-1. Comparison of carbon monoxide concentrations using EPA-approved equipment and portable samplers. ECCO is EPA-approved equipment operated by Clark County Health District and ECB01_P and ECB01_C are portable samplers.

6.2 Upper Air and Surface Meteorological Sites - STI

Operational quality control consisted of daily review of data collected and weekly site visits.

The radar and sodar sites were visited on a weekly schedule for the entire study period and when required when problems arose. The tasks done during the visit included:

Inspecting the RASS and sodar audio sources

Archiving the radar's moments and consensus data and sodar data

Archiving the meteorological tower's data

Checking the computer clocks

Checking the meteorological data logger clocks

Inspecting the radar, sodars, and collocated surface meteorological towers

Checking the Gateway computer

Mailing site logs, maintenance checklists, and archived data to STI

7. REFERENCES

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APPENDIX C

Section Three
The Las Vegas Valley Carbon Monoxide Urban Airshed Model Update Project – Phase II UAM Base Case and Sensitivity Applications (phase 2-base)

3. PHASE II MODELING RESULTS

The UAM was run for base case simulations and various sensitivity simulations for the December 8-9 and December 19-20, 1996 Las Vegas Valley CO episodes, using the input fields described in Section 2. Results from these simulations were compared to observed concentrations and model performance statistics were calculated. During these episodes 10-minute interval CO data were collected at the standard APCD and temporary DRI sites. These data were used to calculate hourly and 8-hourly statistics for model performance. Three sensitivity simulations were carried out under the Phase II modeling task:

1) Use of 200-1000 m averaged profiler wind data (rather than 0-200 m averages in the Base Case) for estimating domain-mean winds for DWM for both episodes;

2) Use 10-minute averaged wind data (instead of hourly in the Base Case) in DWM to generate higher temporal resolution wind fields for UAM;

3) An emissions sensitivity test where estimates of "off-cycle" emissions were included using a modified version of MOBILE5.

BASE CASE SIMULATION RESULTS

Figures 3-1 and 3-2 display time series plots comparing hourly UAM Base Case estimates with observed CO concentrations (from DRI and APCD monitoring sites) for the December 8-9 and December 19-20 episodes, respectively. The solid line represents the model-estimated CO concentrations at the location of the measurement site, while the measurements are indicated by dots. The model is able to estimate both the evening peak and the morning peak at most sites quite well for both episodes. The model is able to track the time evolution of CO concentrations fairly well. For the December 8-9 episode the highest estimated morning concentration occurs an hour later than the highest observed morning concentration at most sites. The morning maximum CO concentrations estimated by the model are lower than the observed maximum at all sites except Charleston and Sacramento, City Center and Shadow Lane. The model slightly underestimates the evening CO maximum concentration at some sites and overestimates at other sites.

The model estimates of CO concentrations for the December 19-20 episode are quite similar to that for the December 8-9 episode in that the model shows a mix of both underestimation and overestimation. For the December 19-20 episode, the highest estimated morning concentration also occurs an hour later than the highest observed morning concentration at most sites, and the morning maximum CO concentration is underestimated at all sites except at City Center, Flamingo, Maycliff and Shadow Lane. Overall, the model is able to track the diurnal pattern of CO quite well.

The spatial distribution of 1-hour maximum predicted CO concentration for the December 8-9 Base Case is shown in Figure 3-3. Note that in such figures as these, the time of the highest CO concentrations varies from cell to cell. The highest measured 1-hour concentration at each site is overlaid onto the prediction contours. Figure 3-4 shows a similar plot of maximum 8-hour estimated concentrations for the December 8-9 Base Case. Figures 3-5 and 3-6 present the corresponding maximum predicted 1-hour and 8-hour CO concentrations, respectively, for the December 19-20 episode.

For the December 8-9 episode, UAM predictions are close to the observed concentrations near the Sunrise Acres area, however, the UAM underestimates most 1-hour peak CO measurements. The UAM estimates a maximum 1-hour CO concentration of 12.7 ppm near McCarran airport, whereas the highest observed concentration near that area is 7 ppm. Another region with high estimated CO lies northwest of Flamingo, near I-15. It must be noted that high predictions cover small areas surrounded by sharp gradients. The UAM estimates markedly lower CO levels in outlying areas, which is consistent with measurement data. For the 8-hour average concentrations, the location of the predicted maximum of 8 ppm is near the site of the observed maximum CO cloud (Sunrise Acres).

For the December 19-20 episode, the UAM predicts a maximum 1-hour concentration of 14 ppm northwest of Flamingo (near I-15) where a 9 ppm maximum concentration was observed. The UAM also estimates a relatively high CO level near Sunrise Acres, however the estimated concentrations are lower than the observed concentrations. The UAM estimates high CO concentration near the McCarran airport (a modeled hot spot with sharp gradients), as was also seen for the December 8-9 episode. The emissions inventory used in the modeling suggests that McCarran airport is a large localized source of CO emissions, which under stagnant conditions leads to high CO concentrations in that area. The peak 8-hour predicted concentration of 9.6 ppm occurs in the same area as the peak 1-hour prediction (in the area of Flamingo and I-15), whereas the nearest maximum 8-hour measurement reached only 4 ppm. The model is able to replicate high concentrations in the area of the measured peak 8-hour CO concentrations (i.e, near Sunrise Acres), however the model estimates are lower than the observations..

A statistical model performance evaluation was performed in accordance with the EPA-guidelines, which are based on comparisons of peak 8-hourly predictions and observations. Statistics were calculated to compare peak estimated and measured concentrations (i.e., paired in space, but not in time), and to compare estimated and measured concentrations for all hours (i.e., paired in space and time). The EPA guidance suggests that performance statistics be based on estimation-observation pairings above 5 ppm. For Phase I modeling a lower cutoff of 1 ppm was used because of the highly localized nature of the observed CO cloud (only a few sites for a few hours measured CO above 5 ppm), and the general nature of the UAM to under estimate the CO pattern. A cutoff of 1 ppm was used for this analysis for the same reasons. The lower concentration threshold enhances the stringency of the EPA acceptance criteria by increasing the number of prediction-observation pairs, which provide more statistically significant measures.

Tables 3-1 and 3-2 show the 1-hour and 8-hour model performance statistics, respectively, for the December 8-9 episode. These statistics only include the observed and predicted pairs for which both the observed and predicted CO concentrations were at least 1 ppm. A 1-hour maximum CO concentration of 13.8 ppm was observed at Marnel Field and the model estimated a maximum of 8.1 ppm at that location. The maximum predicted 1-hour CO anywhere in the domain was 12.7 ppm near the McCarran airport. Thus, the unpaired (in space) 1-hour maximum concentration was underestimated by 1.1 ppm and was located 11 km southwest of the peak observation. The model usually underestimated the highest CO concentrations; the average accuracy of peak prediction was -19%. The overall model predictions showed a bias of -14% and a gross error of ±35% for hourly CO

For the 8-hourly average CO, the bias was -14% and the gross error was ±30%. The maximum 8-hourly CO of 9.6 ppm was observed at Marnel Field, where the model estimated a maximum of 6.8 ppm. The maximum predicted 8-hour CO anywhere in the domain was 8.0 ppm and occurred near Sunrise Acres. The unpaired peak prediction accuracy for the 8-hourly concentrations was -16% and the paired (in space) peak prediction accuracy was -29%. On average the error in timing between the observed and predicted peaks was 1 hour (the predicted peak occurred before the observed peak). According to the EPA guidance, for acceptable CO model performance, the unpaired peak prediction accuracy should be within ±30-35 percent; the paired peak prediction accuracy should be within ±25-30 percent; and the gross error in the timing of the peak prediction should be ±2 hours. Thus, the model performance for December 8-9 is within the acceptable limits.

Tables 3-3 and 3-4 show the 1-hour and 8-hour performance statistics, respectively, for the December 19-20 episode. The highest observed 1-hour CO concentration of 14.3 ppm occurred at the Eastern and Owens site, where the model estimated a maximum concentration of 3.3 ppm. The maximum predicted 1-hour CO anywhere in the domain was 14.0 ppm northwest of Flamingo near I-15, which was in good agreement with the observed maximum in an unpaired sense. The model underestimated the CO peaks on average; the mean peak prediction accuracy was -12%. The overall model predictions showed a bias of -3% and a gross error of ±40%.

For the 8-hour average CO the bias was -9% and the gross error was ±30%. The highest 8-hour CO concentration of 9.5 ppm was observed at Marnel Field, where the model predicted a maximum of 7.4 ppm. The maximum estimated 8-hour CO concentration anywhere in the domain was 9.6 ppm and it occurred northwest of Flamingo near I-15. The unpaired peak prediction accuracy for the 8-hourly concentrations was +1% and the paired (in space) peak prediction accuracy was -22%. On average the gross error in timing between the observed peak and the estimated peak was 3 hours (with the estimated peak occurring before the observed peak). Thus, the model performance was within the acceptable limits for the accuracy in peak predictions, but the timing error exceeded the acceptable limits by 1 hour.

The performance statistics reported above included all the sites for which CO data were available. A separate analysis was performed where only the sites operated by Clark County (APCD sites) were included in calculating the performance statistics. There were two basic reasons for this additional analysis:

- The portable CO monitors used in the Field Study, while demonstrated to be comparable to the APCD instruments in measuring ambient CO levels within 1-2 ppm (see Egami et al., 1998), are nevertheless non-standard devices and cannot be used to officially define CO exceedance events;

- The confirmation of any improvements in Phase II UAM performance over Phase I (in which only APCD data were available) requires that statistical performance measures be determined using a consistent set of measurement data.

The differences in the statistics using the different datasets are summarized in Tables 3-5 and 3-6 for December 8-9 and December 19-20, respectively. For December 8-9, the bias decreased when only the APCD sites were used, whereas the gross error was virtually unchanged. The 8-hour paired peak prediction accuracy improved to -16%, but the average time error in 8-hour peak predictions worsened from -1 to -3 hours when only the APCD sites were used. For December 19-20, the bias decreased for the hourly statistics and increased for the 8-hourly statistics when only the APCD sites were used in the performance statistics. The 8-hour unpaired peak accuracy worsened from 1% for all sites, to 20% for only the APCD sites, which is a result of removing the high measured value at Eastern and Owens; however, this is still within the acceptable limits according to EPA guidance.

Table 3-1. Hourly model performance statistics for the December 8-9, 1996 Base Case.

Peak Prediction Statistics for CO

Peak Observed ppm:	Marnel Field	96344 7 - 96344 8	13.8
Peak Predicted ppm:	Cell (25, 22)	9634317 - 9634318	12.7
Unpaired Peak Prediction Accuracy (%):			-8.1

Peak Predicted/Observed by Site:

Site	Predicted ppm	Predicted hr	Observed ppm	Observed hr	Error ppm	Error %	Time Diff hours
Craig Road/Bemis	1.4	18	1.1	10	.3	27.3	-16
City Center	8.5	20	5.9	7	2.6	43.4	-11
Crestwood	5.7	20	9.8	8	-4.1	-41.6	-12
East Charleston	6.8	21	10.4	7	-3.5	-34.1	-10
East Flamingo	6.8	8	8.3	7	-1.5	-17.7	1
Green Valley	1.8	9	2.2	9	-.4	-17.3	0
Maycliff	8.8	8	9.5	7	-.8	-7.9	1
MGM	4.4	9	7.2	8	-2.8	-39.4	1
Powerline	1.7	8	3.3	7	-1.6	-48.5	1
Paul Meyer	BC*	NA	2.0	8	NA	NA	NA
Pittman	1.7	22	3.8	7	-2.1	-54.7	-9
Sunrise Acres	7.9	8	11.8	7	-3.9	-32.8	1
Shadow Lane	7.3	9	5.6	9	1.7	30.9	0
Winterwood	5.6	0	5.4	7	.2	3.3	-7
East Charleston DRI	6.8	21	11.8	7	-5.0	-41.9	-10
Marnel Field	8.1	8	13.8	7	-5.7	-41.4	1
Eastern & Bonanza	8.6	8	11.1	7	-2.5	-22.3	1
Eastern and Owens	4.4	19	12.2	7	-7.8	-63.9	-12
Bruce and Grayson	5.3	23	6.6	19	-1.3	-20.2	4
Carson and 17th	7.9	20	9.0	8	-1.1	-12.2	-12
Eastern and Tioga	5.6	8	6.9	8	-1.3	-18.6	0
St. Louis & Atlantic	6.1	20	6.1	19	.0	.3	1
Charleston and Pecos	7.3	8	10.9	7	-3.6	-33.2	1
Charleston & Sacrame	8.7	8	9.4	7	-.7	-7.8	1
Paradise Valley Park	4.0	8	3.5	8	.5	14.3	0
Del Robison School	5.7	3	7.0	7	-1.3	-19.0	-4
Silver Bowl	2.7	8	4.2	9	-1.5	-35.7	-1
Alhambra & Cordova	6.7	8	8.6	7	-1.9	-22.1	1
Average:					-1.8	-19.0	-3
Number of Stations:	28						
Number of valid peak pairs:	27						

Overall Statistics for CO

For Concentrations above	(ppm):	1.0
Average UAM Prediction	(ppm):	3.2
Average Observation	(ppm):	4.0
Difference in Averages	(ppm):	-.8
	(%):	-19.5
Bias	(ppm):	-1.1
	(%):	-14.3
Error	(ppm):	1.7
	(%):	35.4
RMS Error	(ppm):	2.3
Number of total pairs:		560
Number of valid pairs:		406
	(%)	72.5

BC*: Below Cutoff of 1 ppm

Table 3-2. 8-hourly model performance statistics for the December 8-9, 1996 Base Case.

Peak Prediction Statistics for CO

Peak Observed ppm: Marnel Field	9634319 - 96344 3	9.6
Peak Predicted ppm: Cell (28, 32)	9634319 - 96344 3	8.0
Unpaired Peak Prediction Accuracy (%):		-16.1

Peak Predicted/Observed by Site:

Site	Predicted ppm	Predicted hr	Observed ppm	Observed hr	Error ppm	Error %	Time Diff hours
Craig Road/Bemis	BC	NA	BC	NA	NA	NA	NA
City Center	6.8	18	4.4	18	2.4	55.7	0
Crestwood	4.2	19	5.3	2	-1.1	-21.0	-7
East Charleston	5.9	20	7.2	19	-1.3	-18.0	1
East Flamingo	3.5	3	4.4	2	-.9	-21.2	1
Green Valley	BC	NA	1.4	3	NA	NA	NA
Maycliff	5.7	2	6.3	1	-.7	-10.6	1
MGM	1.8	3	4.1	3	-2.3	-55.4	0
Powerline	BC	NA	1.8	3	NA	NA	NA
Paul Meyer	BC	NA	BC	NA	NA	NA	NA
Pittman	1.3	17	2.0	3	-.6	-32.8	-10
Sunrise Acres	6.6	19	7.9	19	-1.3	-16.1	0
Shadow Lane	4.9	17	3.8	3	1.1	28.6	-10
Winterwood	5.0	23	3.9	1	1.1	27.0	-2
East Charleston DRI	5.9	20	7.9	19	-2.0	-24.9	1
Marnel Field	6.8	19	9.6	19	-2.7	-28.6	0
Eastern & Bonanza	7.5	19	9.1	18	-1.6	-17.5	1
Eastern and Owens	3.5	18	9.5	18	-6.0	-63.4	0
Bruce and Grayson	4.7	18	4.6	18	.1	2.4	0
Carson and 17th	5.7	19	6.3	2	-.6	-9.9	-7
Eastern and Tioga	3.0	3	3.9	3	-.9	-22.8	0
St. Louis & Atlantic	4.8	19	BC	NA	NA	NA	NA
Charleston and Pecos	5.9	21	9.4	22	-3.5	-37.2	-1
Charleston & Sacrame	6.6	2	7.8	19	-1.2	-15.6	7
Paradise Valley Park	2.5	2	1.1	3	1.3	116.8	-1
Del Robison School	4.9	1	4.1	18	.8	21.0	7
Silver Bowl	1.7	2	BC	NA	NA	NA	NA
Alhambra & Cordova	4.2	18	5.9	2	-1.8	-29.9	-8
Average:					-1.0	-7.9	-1

Number of Stations: 28
Number of valid peak pairs: 22

Overall Statistics for CO

For Concentrations above	(ppm):	1.0
Average UAM Prediction	(ppm):	3.4
Average Observation	(ppm):	4.2
Difference in Averages	(ppm):	-.8
	(%):	-18.5
Bias	(ppm):	-1.0
	(%):	-13.9
Error	(ppm):	1.4
	(%):	29.9
RMS Error	(ppm):	1.9

Number of total pairs: 364
Number of valid pairs: 273
(%) 75.0

Table 3-3. Hourly model performance statistics for the December 19-20, 1996 Base Case

Peak Prediction Statistics for CO

Peak Observed ppm:	Eastern and Owens	96355 6 - 96355 7	14.3
Peak Predicted ppm:	Cell (24, 28)	9635420 - 9635421	14.0
Unpaired Peak Prediction Accuracy (%):			-2.0

Peak Predicted/Observed by Site:

Site	Predicted ppm	Predicted hr	Observed ppm	Observed hr	Error ppm	Error %	Time Diff hours
Boulder City Library	BC	NA	BC	NA	NA	NA	NA
Craig Road/Bemis	BC	NA	BC	NA	NA	NA	NA
City Center	8.6	18	7.5	23	1.1	14.3	-5
Crestwood	7.7	23	9.0	7	-1.3	-14.7	-8
East Charleston	8.8	20	10.4	7	-1.6	-15.9	-11
East Flamingo	9.6	8	5.5	6	4.1	74.5	2
Green Valley	1.5	10	2.9	7	-1.4	-49.0	3
Maycliff	10.4	21	7.5	19	2.9	38.3	2
MGM	5.7	9	7.2	7	-1.5	-21.4	2
Powerline	1.7	9	3.1	7	-1.4	-44.2	2
Paul Meyer	1.0	16	2.0	8	-1.0	-48.0	-16
Pittman	2.7	9	3.8	7	-1.1	-29.5	2
Sunrise Acres	9.3	19	10.8	7	-1.5	-13.9	-12
Shadow Lane	9.3	18	6.8	20	2.4	36.0	-2
Winterwood	6.5	21	5.3	7	1.2	22.6	-10
East Charleston DRI	8.8	20	11.2	7	-2.4	-21.9	-11
Marnel Field	8.9	19	13.1	7	-4.2	-31.8	-12
Eastern & Bonanza	9.2	18	11.6	7	-2.4	-20.3	-13
Eastern and Owens	3.3	18	14.3	6	-11.1	-77.3	-12
Bruce and Grayson	4.5	18	7.0	8	-2.5	-35.6	-14
Carson and 17th	9.0	19	10.7	7	-1.7	-16.3	-12
Eastern and Tioga	8.7	21	8.2	8	.5	6.3	-11
St. Louis & Atlantic	9.9	20	11.4	7	-1.5	-13.0	-11
Charleston & Sacrame	7.9	20	8.7	7	-.8	-8.9	-11
Paradise Valley Park	5.3	9	5.3	8	-.1	-.9	1
Del Robison School	3.9	6	4.9	7	-1.0	-21.0	-1
Silver Bowl	3.1	8	4.3	8	-1.2	-28.6	0
Alhambra & Cordova	10.2	19	9.2	20	1.0	10.9	-1
Average:					-1.0	-11.9	-6
Number of Stations:	28						
Number of valid peak pairs:	26						

Overall Statistics for CO

For Concentrations above	(ppm):	1.0
Average UAM Prediction	(ppm):	3.6
Average Observation	(ppm):	4.0
Difference in Averages	(ppm):	-.4
	(%):	-8.9
Bias	(ppm):	-.6
	(%):	-3.4
Error	(ppm):	1.7
	(%):	39.8
RMS Error	(ppm):	2.3
Number of total pairs:		560
Number of valid pairs:		439
	(%)	78.4

Table 3-4. 8-hourly model performance statistics for the December 19-20, 1996 Base Case

Peak Prediction Statistics for CO

Peak Observed ppm: Marnel Field	96355 1 - 96355 9	9.5
Peak Predicted ppm: Cell (24, 27)	9635418 - 96355 2	9.6
Unpaired Peak Prediction Accuracy (%):		.6

Peak Predicted/Observed by Site:

Site	Predicted ppm	Predicted hr	Observed ppm	Observed hr	Error ppm	Error %	Time Diff hours
Boulder City Library	BC	NA	BC	NA	NA	NA	NA
Craig Road/Bemis	BC	NA	BC	NA	NA	NA	NA
City Center	6.3	17	4.7	22	1.7	35.4	-5
Crestwood	6.3	18	6.5	18	-.2	-3.4	0
East Charleston	7.6	18	7.9	1	-.3	-4.3	-7
East Flamingo	5.1	17	4.1	17	1.0	24.6	0
Green Valley	BC	NA	1.9	3	NA	NA	NA
Maycliff	7.0	19	5.9	18	1.1	18.2	1
MGM	2.3	16	4.6	3	-2.2	-48.6	-11
Powerline	1.1	17	1.9	3	-.8	-43.9	-10
Paul Meyer	BC	NA	1.3	3	NA	NA	NA
Pittman	1.5	17	2.4	18	-.9	-35.7	-1
Sunrise Acres	7.7	18	8.0	0	-.3	-4.3	-6
Shadow Lane	6.8	17	5.6	18	1.2	21.9	-1
Winterwood	3.9	17	3.0	17	.9	31.8	0
East Charleston DRI	7.6	18	8.6	1	-1.1	-12.3	-7
Marnel Field	7.4	18	9.5	1	-2.1	-22.0	-7
Eastern & Bonanza	6.4	17	7.8	1	-1.5	-18.7	-8
Eastern and Owens	2.1	17	8.4	17	-6.3	-75.1	0
Bruce and Grayson	3.3	17	3.7	18	-.4	-10.9	-1
Carson and 17th	6.8	18	7.5	1	-.8	-10.2	-7
Eastern and Tioga	6.6	18	6.2	22	.4	6.3	-4
St. Louis & Atlantic	8.5	19	8.9	18	-.4	-4.8	1
Charleston & Sacrame	5.8	18	5.6	17	.2	3.7	1
Paradise Valley Park	3.4	17	2.8	2	.6	20.4	-9
Del Robison School	2.3	3	3.3	17	-1.0	-30.6	10
Silver Bowl	1.6	18	1.3	3	.4	28.1	-9
Alhambra & Cordova	7.7	18	7.4	18	.3	3.9	0
Average:					-.4	-5.4	-3
Number of Stations:	28						
Number of valid peak pairs:	24						

Overall Statistics for CO

For Concentrations above	(ppm):	1.0
Average UAM Prediction	(ppm):	3.8
Average Observation	(ppm):	4.3
Difference in Averages	(ppm):	-.5
	(%):	-11.8
Bias	(ppm):	-.6
	(%):	-8.8
Error	(ppm):	1.3
	(%):	29.5
RMS Error	(ppm):	1.7
Number of total pairs:		364
Number of valid pairs:		312
	(%)	85.7

Table 3-5. Comparison of performance statistics using all sites and using only the Clark County APCD sites for December 8-9, 1996 CO episode Base Case.

	APCD Sites		All Sites	
Performance Measure	**Hourly**	**8-hourly**	**Hourly**	**8-hourly**
Peak observed (ppm)	11.8	7.9	13.8	9.6
Peak site	Sunrise Acres	Sunrise Acres	Marnel Field	Marnel Field
Peak predicted (paired) (ppm)	7.9	6.6	8.1	6.8
Peak predicted (unpaired) (ppm)	12.7	8.0	12.7	8.0
Paired peak prediction accuracy (%)	-33	-16	-41	-29
Unpaired peak prediction accuracy (%)	8	2	-8	-16
Average timing error in peak (hours)	-5	-3	-3	-1
Average observed (ppm)	3.1	3.1	4.0	4.2
Average predicted (ppm)	2.7	2.8	3.2	3.4
Bias (%)	-9	-12	-14	-14
Gross Error (%)	36	30	35	30

Table 3-6. Comparison of performance statistics using all sites and using only the Clark County APCD sites for December 19-20, 1996 CO episode Base Case.

	APCD Sites		All Sites	
Performance Measure	**Hourly**	**8-hourly**	**Hourly**	**8-hourly**
Peak observed (ppm)	10.8	8.0	14.3	9.5
Peak site	Sunrise Acres	Sunrise Acres	Eastern /Owens	Marnel Field
Peak predicted (paired) (ppm)	9.3	7.7	3.3	7.4
Peak predicted (unpaired) (ppm)	14.0	9.6	14.0	9.6
Paired peak prediction accuracy (%)	-14	-4	-77	-22
Unpaired peak prediction accuracy (%)	30	20	-2	-1
Average timing error in peak (hours)	-4	-4	-6	-3
Average observed (ppm)	3.3	3.5	4.0	4.3
Average predicted (ppm)	3.2	3.3	3.6	3.8
Bias (%)	-1	-11	-3	-9
Gross Error (%)	42	30	40	30

UAM SENSITIVITY TESTS

Several sensitivity simulations were carried out in the Phase I modeling to evaluate the effect of input variations on estimated CO concentrations in the LVV. These sensitivity tests explored variations in meteorological parameters and emissions. The Phase I sensitivity results suggested that the CO concentrations were most sensitive to emissions changes and were effected very little by changes in meteorological parameters. In Phase II, two sensitivity simulations were carried out for each episode where the meteorological parameters were varied, and one sensitivity simulations was carried out with alternate emission rates. The first meteorological parameter that was changed was the domain-mean winds supplied to the DWM. In the Base Case the domain-mean winds were calculated by averaging profiler winds from the surface to 200 m, which results in lower wind speeds. In the sensitivity case, profiler winds between 200-1000 m were averaged to determine the domain-mean winds, resulting in higher speeds and sometimes different direction compared to the Base Case. This sensitivity simulation is referred to as the high DMW (domain-mean wind) case.

In the second meteorological sensitivity test, 10-minute wind fields were generated by DWM and supplied to UAM instead of hourly winds as in the Base Case. Surface stations operated by APCD report wind data every ten minutes, so it was natural to use a 10-minute interval for the higher temporal resolution wind fields. The upper air profiler data were reduced to 15 minute averages and then interpolated to 10-minute data before supplying them to the DWM. The main reason for selecting this sensitivity test is that the use of hourly averaged wind fields removes the stochastic nature of the real wind fields during stagnation conditions. The stochastic portion of the real wind fields is often the dominant component during stagnation because the motions associated with weak turbulence exceed the motions induced by the mean flow. These effects are damped out with the use of hourly averaged wind data, since the net effect of hourly averaged winds is to artificially transport mass on the grid in a constant pattern for the duration of an entire hour. Using the 10-minute average winds incorporates more of this stochastic component in the wind fields and resolves some of the wind meander that occurs under light wind conditions.

High DMW Case

The model performance results for the high DMW case are compared to those from the Base Case for the December 8-9 and the December 19-20 episodes, respectively, in Tables 3-7 and 3-8. The statistics were calculated using all the sites for which data were available. For December 8-9, the hourly predicted peak (paired in space) decreased from 8.1 ppm in the Base Case to 7.7 ppm in the high DMW case. Similarly, the 8-hourly predicted peak (paired in space) decreased from 6.8 ppm in the Base Case to 6.6 ppm in the high DMW case. The hourly unpaired peak prediction was also lower in the high DMW case, but the 8-hour unpaired peak increased from 8 ppm in the Base Case to 8.2 ppm in the high DMW case. The overall average 1-hour and 8-hour CO concentrations predicted by the model decreased slightly in the high DMW case and that resulted in a larger negative bias and also a slightly increased gross error. It was expected that the high DMW case would have lowered CO concentrations because it generally increases the winds in the domain, and therefore the rate of ventilation. The overall effects of higher domain-mean winds are small for the December 8-9 episode, and the most significant changes were the larger negative bias and gross error.

Similar effects from increasing the domain-mean winds were found for the December 19-20, 1996 episode, as shown in Table 3-8. The space-paired peak prediction accuracy for 1-hour CO concentration decreased from 3.3 ppm in the Base Case to 2.9 ppm in the high DMW case, and for 8-hour CO decreased from 7.4 ppm to 6.7 ppm. There was virtually no change in the unpaired peak predictions. Overall, hourly and 8-hourly concentrations were reduced, leading to a larger negative bias for the high DMW case, but the increase was smaller than what was seen for the December 8-9 episode. Interestingly, there was a slight improvement in the normalized error for the high DMW case. Overall, the effect of the higher domain-mean wind is minor, and not significant. This result suggests that UAM uncertainty associated with how the domain-mean winds area specified in DWM has minimal effect on the CO concentrations in this application. The likely reason for this is that gridded winds in the central portion of the LV Valley are defined from the dense network of monitors, rather than the domain-mean wind inputs.

Table 3-7. Summary of statistics for various UAM cases applied to the December 8-9, 1996 CO episode.

	Base Case		High DMW		10-Minute Winds	
Performance Measure	**Hourly**	**8-hourly**	**Hourly**	**8-hourly**	**Hourly**	**8-hourly**
Peak observed (ppm)	13.8	9.6	13.8	9.6	13.8	9.6
Peak site	Marnel Field	Marnel Field	Marnel Field	Marnel Field	Marnel Field	Marnel Field
Peak predicted (paired) (ppm)	8.1	6.8	7.7	6.6	8.2	6.7
Peak predicted (unpaired) (ppm)	12.7	8.0	11.8	8.2	13.1	7.6
Paired peak prediction accuracy (%)	-41	-29	-44	-31	-41	-30
Unpaired peak prediction accuracy (%)	-8	-16	-14	-14	-5	-21
Average timing error in peak (hours)	-3	-1	-4	-2	-2	-2
Average observed (ppm)	4.0	4.2	4.0	4.2	4.0	4.2
Average predicted (ppm)	3.2	3.4	3.0	3.2	3.2	3.4
Bias (%)	-14	-14	-21	-20	-15	-14
Gross Error (%)	35	30	37	33	35	30

Table 3-8. Summary of statistics for various UAM cases applied to the December 19-20, 1996 CO episode.

	Base Case		High DMW		10-Minute Winds	
Performance Measure	**Hourly**	**8-hourly**	**Hourly**	**8-hourly**	**Hourly**	**8-hourly**
Peak observed (ppm)	14.3	9.5	14.3	9.5	14.3	9.5
Peak site	Eastern/ Owens	Marnel Field	Eastern/ Owens	Marnel Field	Eastern/ Owens	Marnel Field
Peak predicted (paired) (ppm)	3.3	7.4	2.9	6.7	3.3	7.8
Peak predicted (unpaired) (ppm)	14.0	9.6	13.9	9.6	13.9	9.7
Paired peak prediction accuracy (%)	-77	-22	-80	-29	-77	-18
Unpaired peak prediction accuracy (%)	-2	1	-3	0	-3	1
Average timing error in peak (hours)	-6	-3	-6	-2	-7	-3
Average observed (ppm)	4.0	4.3	4.0	4.3	4.0	4.3
Average predicted (ppm)	3.6	3.8	3.5	3.6	3.8	4.0
Bias (%)	-3	-9	-7	-14	1	-4
Gross Error (%)	40	30	39	28	40	30

Figures 3-7 and 3-8 show the differences in 1-hour maximum predicted CO concentrations between the high DMW case and the Base Case, for the December 8-9 episode and the December 19-20 episode, respectively. In these plots, positive differences indicate that the sensitivity run increased maximum CO. For December 8-9, the difference pattern shows a positive plume of 2 ppm extending northeast of downtown Las Vegas and a 2 ppm increase near Spring Mountain Road and I-15. Isolated areas of CO decrease near areas of positive difference indicate shifts in the CO transport, as indicated by minima along highway 95, along I-15 near Flamingo, and near the McCarran airport. Overall, the general difference pattern appears to reduce CO in the southern areas, and increase it in the northern areas, which suggests a general shift in CO transport (in layers aloft) from southward to northward.

For the December 19-20 episode, the notable difference between the predicted patterns for the high DMW case and the Base Case occurs near McCarran airport, where CO is reduced by as much as 3 ppm. Note that in this episode, the CO pattern is generally shifted southward. Otherwise, the differences are smaller than seen for December 8-9; less sensitivity to specification of domain-mean wind in this episode further suggests that the vertical wind profile was less variable than in the December 8-9 episode.

10-Minute Winds Case

It was expected that using 10-minute wind inputs would improve the characterization of the transport and dispersion occurring under the stagnation conditions that are associated with CO exceedance events. The results shown in Tables 3-7 and 3-8 indicate that the effect of 10-minute winds is minimal and even smaller than the effect of high domain-mean winds, though in the opposite direction. For the December 8-9 episode, the paired peak predicted hourly concentration increased slightly (0.1 ppm) and the paired peak 8-hour concentration decreased slightly (0.1 ppm). The unpaired 1-hour peak concentration increased from 12.7 ppm in the Base Case to 13.1 ppm in the 10-minute winds case, whereas the unpaired 8-hour peak concentration decreased from 8.0 ppm to 7.6 ppm. There are no differences in the average predicted concentrations between the Base Case and the 10-minute winds case, and also virtually no difference in the bias and gross error statistics.

The differences between the Base Case and the 10-minute winds case for the December 19-20 episode are small as well. The paired peak 8-hour concentration increased from 7.4 ppm to 7.8 ppm while the unpaired peak concentration decreased slightly (0.1 ppm). The average predicted concentrations (both 1-hour and 8-hour) increased by 0.2 ppm in the 10-minute winds case, thereby reducing the negative bias by 4-5 percentage points. The normalized error remained unchanged. The spatial plots of differences in hourly peak CO are shown in Figures 3-9 and 3-10. In both episodes, 10-minute winds are seen to generally reduce peak CO slightly, with very small isolated areas of positive and negative differences of a 1-3 ppm.

Emissions Sensitivity Case

In the emissions sensitivity case, the estimated contribution from off-cycle emissions were increased using a modified version of MOBILE5. This sensitivity simulation is referred to as the high emissions case. Table 3-9 shows the hourly domain-wide emissions rates for the Base Case and the high emissions case for the two episodes. Total emissions increased from 225 tons in the Base case to 261 tons (16%) for the December 8-9 episode, and from 316 tons to 360 tons (14%) for the December 19-20 episode. Thus, the predicted CO concentrations were expected to be significantly higher in this sensitivity case throughout each of the simulations.

The model performance results of the high emissions case for the December 8-9 episode are compared to the Base Case in Table 3-10. Model performance for 1-hour and 8-hour predictions is better in the high emissions case. The paired peak predicted hourly CO concentration increased from 8.1 ppm in the Base Case to 9.2 ppm in the high emissions case (the peak observation was 13.8 ppm). The paired peak 8-hour CO increased from 6.8 ppm to 7.8 ppm (the peak observation was 9.6 ppm). Both the paired and unpaired peak prediction accuracy improved for the high emissions case for both 1-hour and 8-hour averages. The bias improved from -13.9% to -2.1%, and the mean normalized error also showed improvement.

Table 3-9. Hourly domain-wide CO emissions (tons) in the Base Case and High Emissions Case for the two modeling episodes.

	December 8-9		December 19-20	
Hour	**Base Case**	**High Emissions Case**	**Base Case**	**High Emissions Case**
15	14	17	33	38
16	15	17	27	31
17	14	17	26	30
18	14	16	20	23
19	13	14	17	20
20	11	13	15	16
21	9	10	13	15
22	8	9	10	12
23	7	8	9	10
0	6	6	7	8
1	5	5	6	6
2	4	5	5	6
3	4	5	5	6
4	5	6	6	7
5	10	11	12	13
6	16	18	19	22
7	19	23	24	27
8	17	20	21	24
9	18	20	21	24
10	18	21	21	24
Total	225	261	316	360

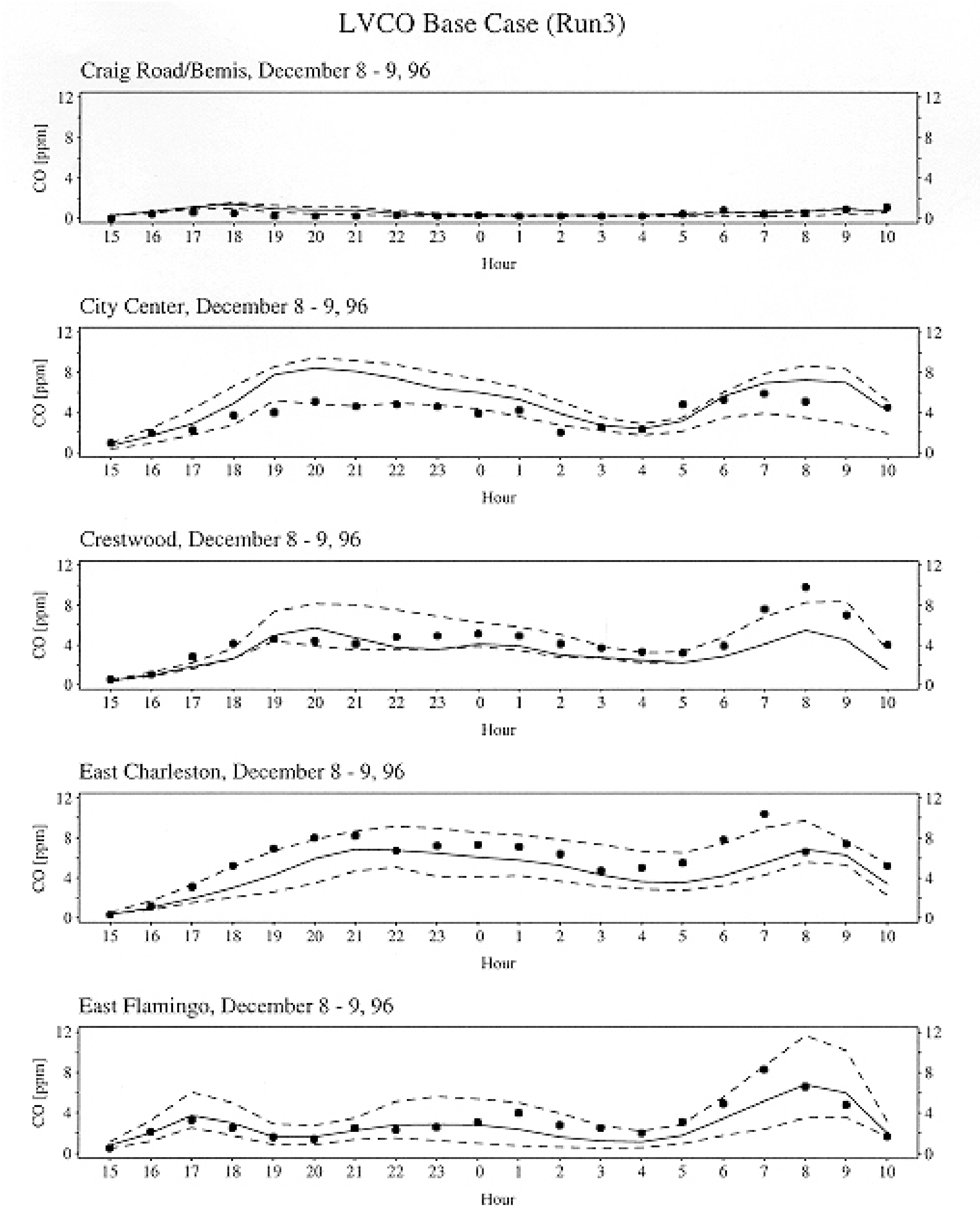
Table 3-10. Comparison of model performance measures between the Base Case and High Emissions Case for December 8-9, 1996.

	Base Case		**High Emissions Case**	
Performance Measure	**Hourly**	**8-hourly**	**Hourly**	**8-hourly**
Peak observed (ppm)	13.8	9.6	13.8	9.6
Peak site	Marnel Field	Marnel Field	Marnel Field	Marnel Field
Peak predicted (paired) (ppm)	8.1	6.8	9.2	7.8
Peak predicted (unpaired) (ppm)	12.7	8.0	13.5	9.0
Paired peak prediction accuracy (%)	-41	-29	-33	-19
Unpaired peak prediction accuracy (%)	-8	-16	-3	-6
Average timing error in peak (hours)	-3	-1	-3	-1
Average observed (ppm)	4.0	4.2	4.0	4.2
Average predicted (ppm)	3.2	3.4	3.7	3.9
Bias (%)	-14	-14	-2	-2
Gross Error (%)	35	30	35	29

Table 3-11 shows a comparison of model performance between the Base Case and high emissions case for the December 19-20 episode. Model performance in the high emissions case improved in some respects and degraded in others relative to the Base Case. The 8-hour paired peak prediction accuracy improved from -22% in the Base Case to -13%; the 8-hour unpaired peak prediction accuracy worsened from 1% to 14%. The 8-hour bias improved from -9% to +2%, but the 8-hour gross error increased 30% to 32%. Overall, the performance for the December 19-20 episode is better in the high emissions case. The resulting spatial differences in peak 1-hour CO concentrations are provided in Figure 3-11 for the January 19-20 episode. The increase in mobile emission rates are seen to increase peak CO concentrations by about 1 ppm in central Las Vegas (particularly near the area of Flamingo and I-15), and by lower amounts along the major traffic arteries extending outward. A similar pattern occurred for the December 8-9 episode (not shown).

Table 3-11. Comparison of model performance measures between the Base Case and High Emissions Case for December 19-20, 1996.

	Base Case		High Emissions Case	
Performance Measure	**Hourly**	**8-hourly**	**Hourly**	**8-hourly**
Peak observed (ppm)	14.3	9.5	14.3	9.5
Peak site	Eastern/ Owens	Marnel Field	Eastern/ Owens	Marnel Field
Peak predicted (paired) (ppm)	3.3	7.4	3.8	8.3
Peak predicted (unpaired) (ppm)	14.0	9.6	15.8	10.9
Paired peak prediction accuracy (%)	-77	-22	-73	-13
Unpaired peak prediction accuracy (%)	-2	-1	-10	-14
Average timing error in peak (hours)	-6	-3	-6	-3
Average observed (ppm)	4.0	4.3	4.0	4.3
Average predicted (ppm)	3.6	3.8	4.1	4.3
Bias (%)	-3	-9	-9	-2
Gross Error (%)	40	30	43	32



LVCO Base Case (Run3)
Craig Road/Bemis, December 8 - 9, 96
City Center, December 8 - 9, 96
Crestwood, December 8 - 9, 96
East Charleston, December 8 - 9, 96
East Flamingo, December 8 - 9, 96
CO [ppm]
Hour
0
4
8
12
15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10

Figure 3-1. Comparison of observed CO concentrations (•••) against UAM estimated CO concentrations (____) for December 8-9, Base Case.

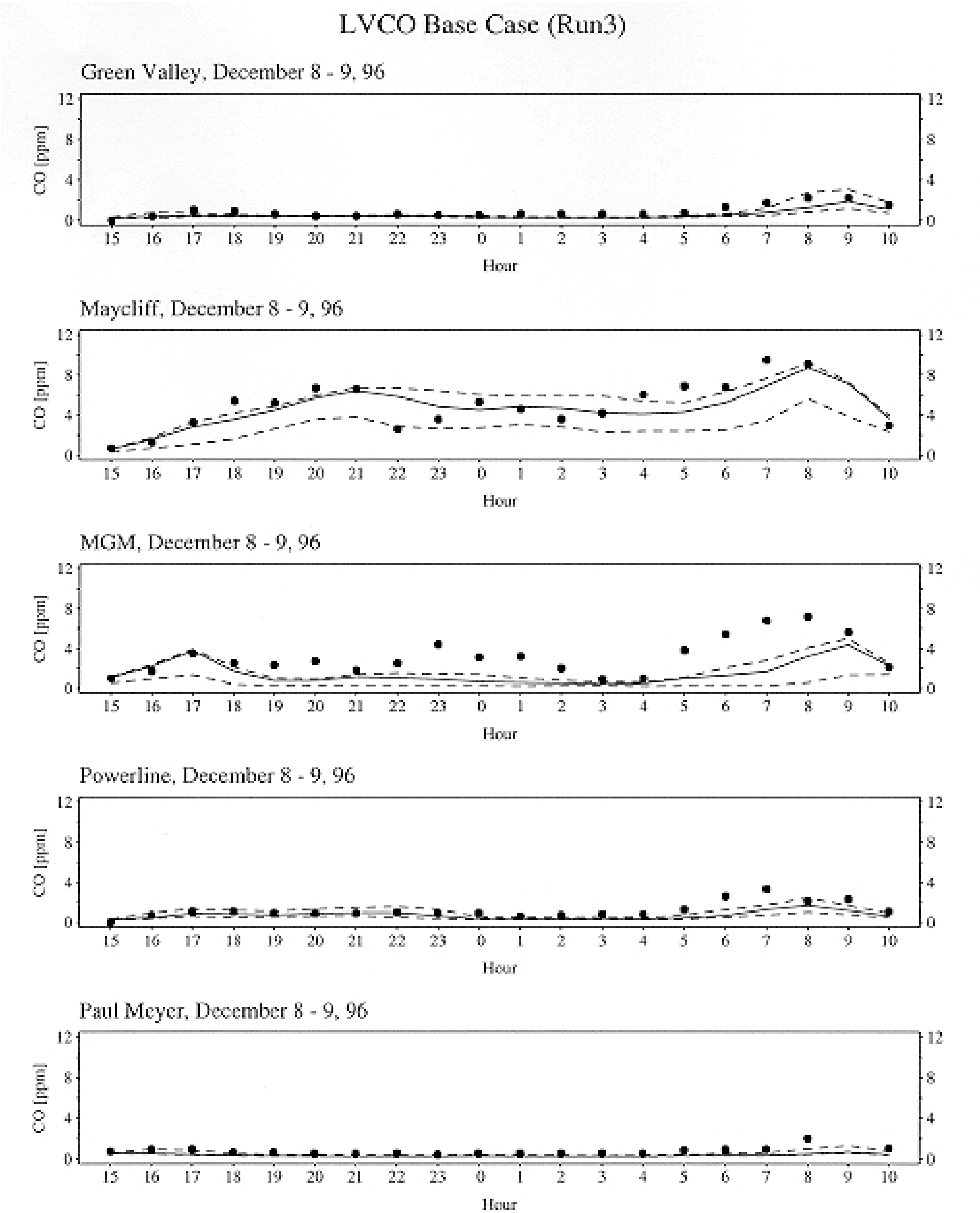

LVCO Base Case (Run3)
Green Valley, December 8 - 9, 96
CO [ppm]
Hour
Maycliff, December 8 - 9, 96
CO [ppm]
Hour
MGM, December 8 - 9, 96
CO [ppm]
Hour
Powerline, December 8 - 9, 96
CO [ppm]
Hour
Paul Meyer, December 8 - 9, 96
CO [ppm]
Hour

Figure 3-1. Continued.

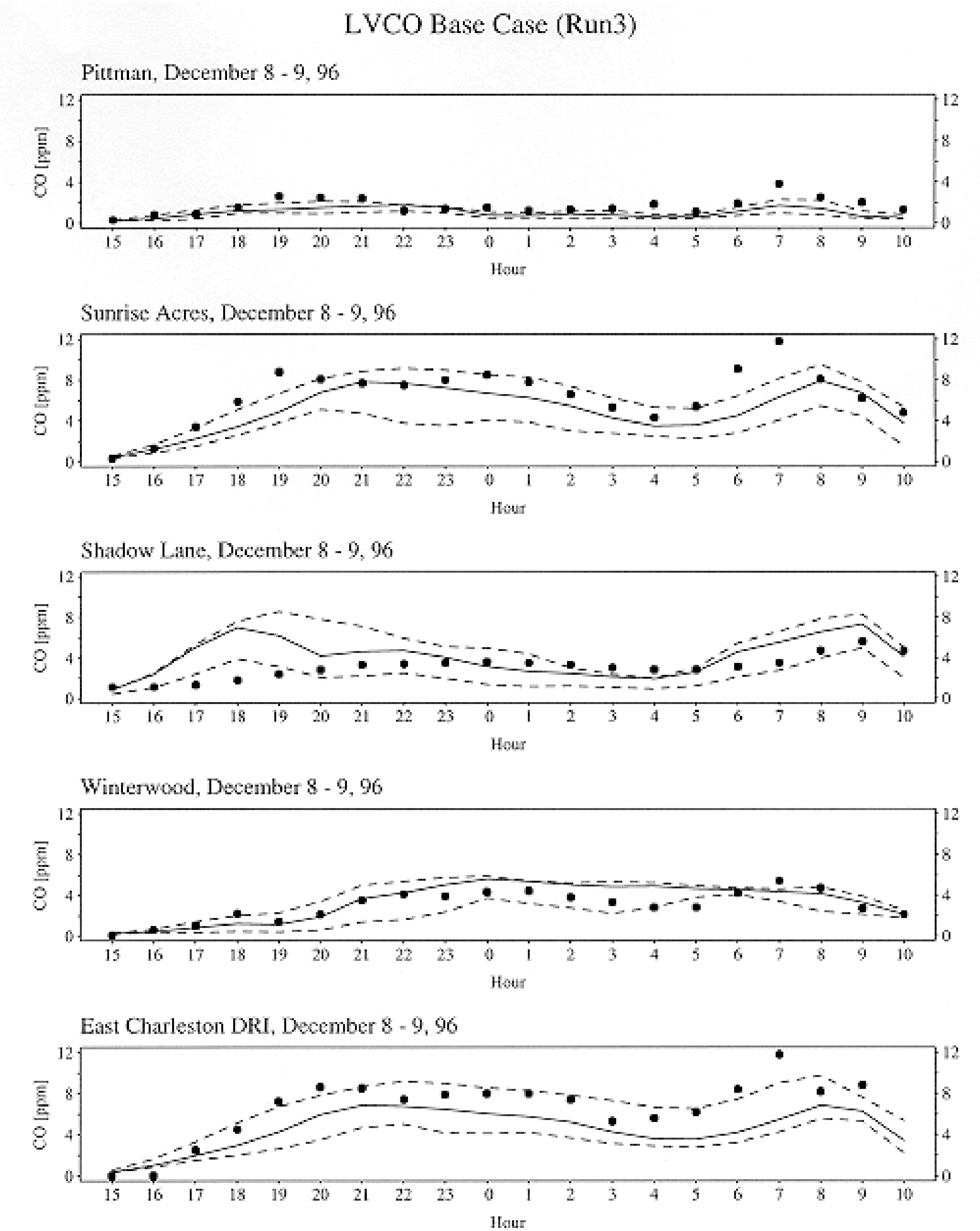

LVCO Base Case (Run3)
Pittman, December 8 - 9, 96
Sunrise Acres, December 8 - 9, 96
Shadow Lane, December 8 - 9, 96
Winterwood, December 8 - 9, 96
East Charleston DRI, December 8 - 9, 96
CO [ppm]
0
4
8
12
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
8
9
10
Hour

Figure 3-1. Continued.

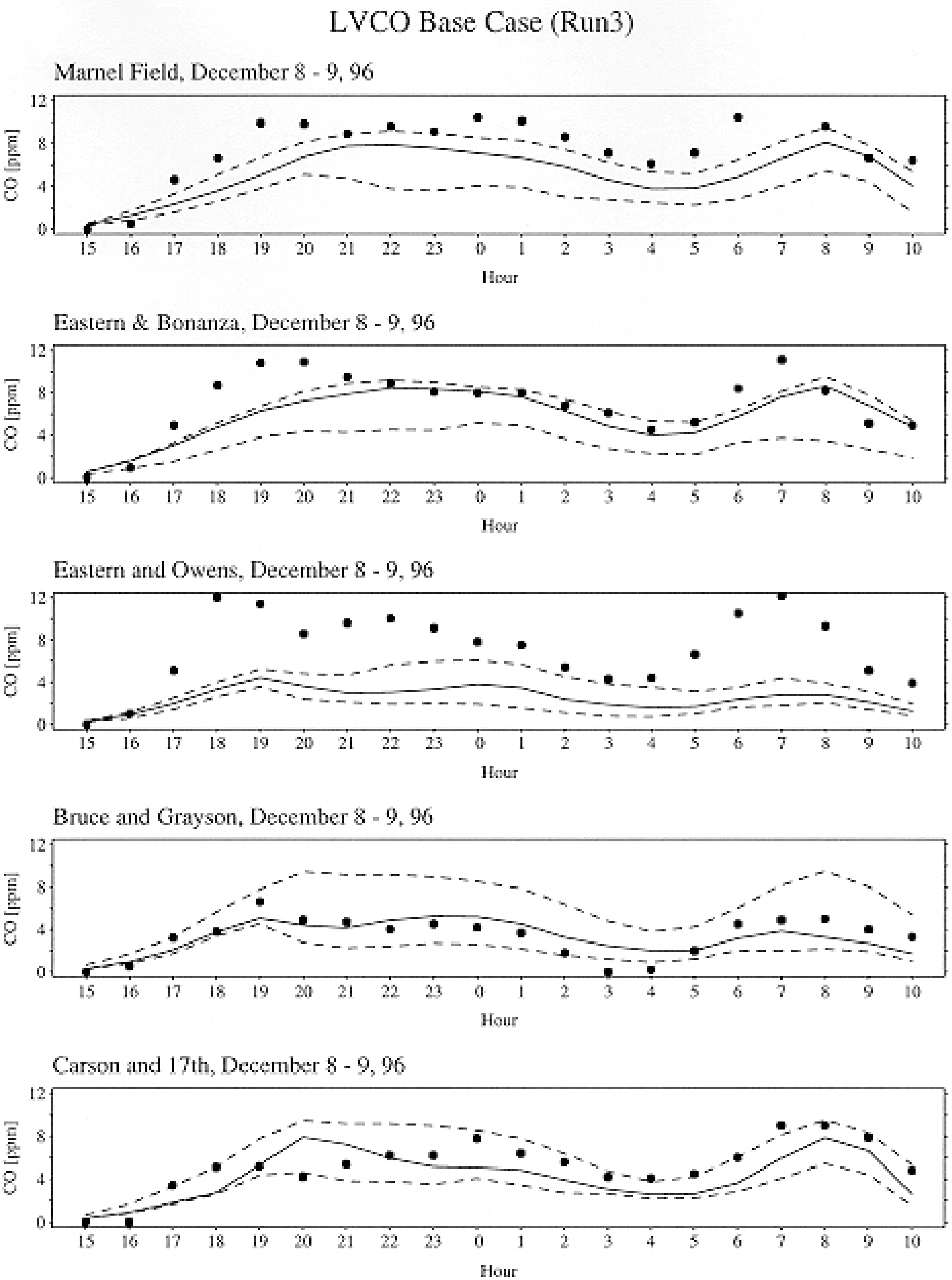
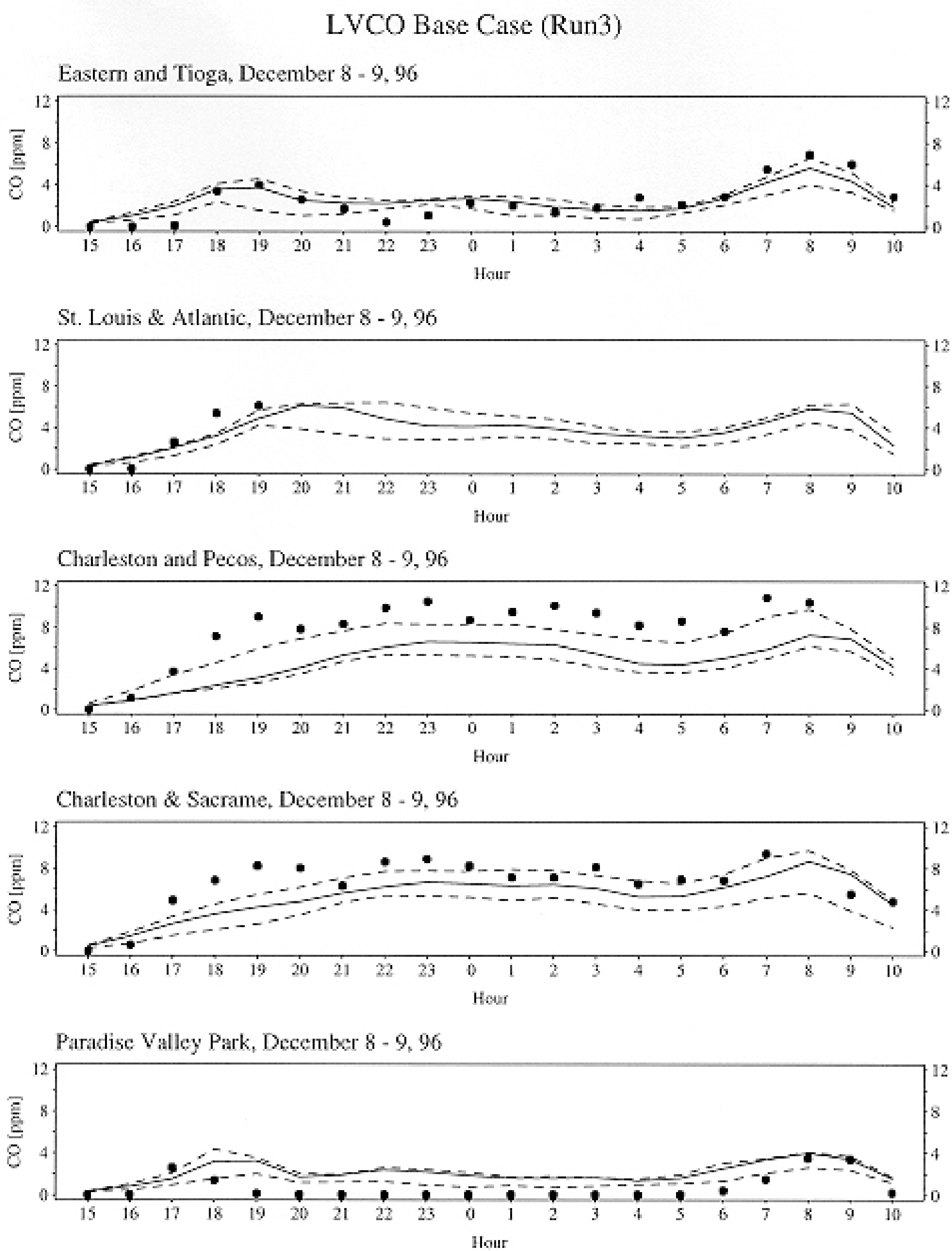

LVCO Base Case (Run3)
Marnel Field, December 8 - 9, 96
Eastern & Bonanza, December 8 - 9, 96
Eastern and Owens, December 8 - 9, 96
Bruce and Grayson, December 8 - 9, 96
Carson and 17th, December 8 - 9, 96
CO [ppm]
0
4
8
12
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
8
9
10
Hour

Figure 3-1. Continued.


LVCO Base Case (Run3)
Eastern and Tioga, December 8 - 9, 96
St. Louis & Atlantic, December 8 - 9, 96
Charleston and Pecos, December 8 - 9, 96
Charleston & Sacrame, December 8 - 9, 96
Paradise Valley Park, December 8 - 9, 96
CO [ppm]
Hour
0
4
8
12
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
8
9
10

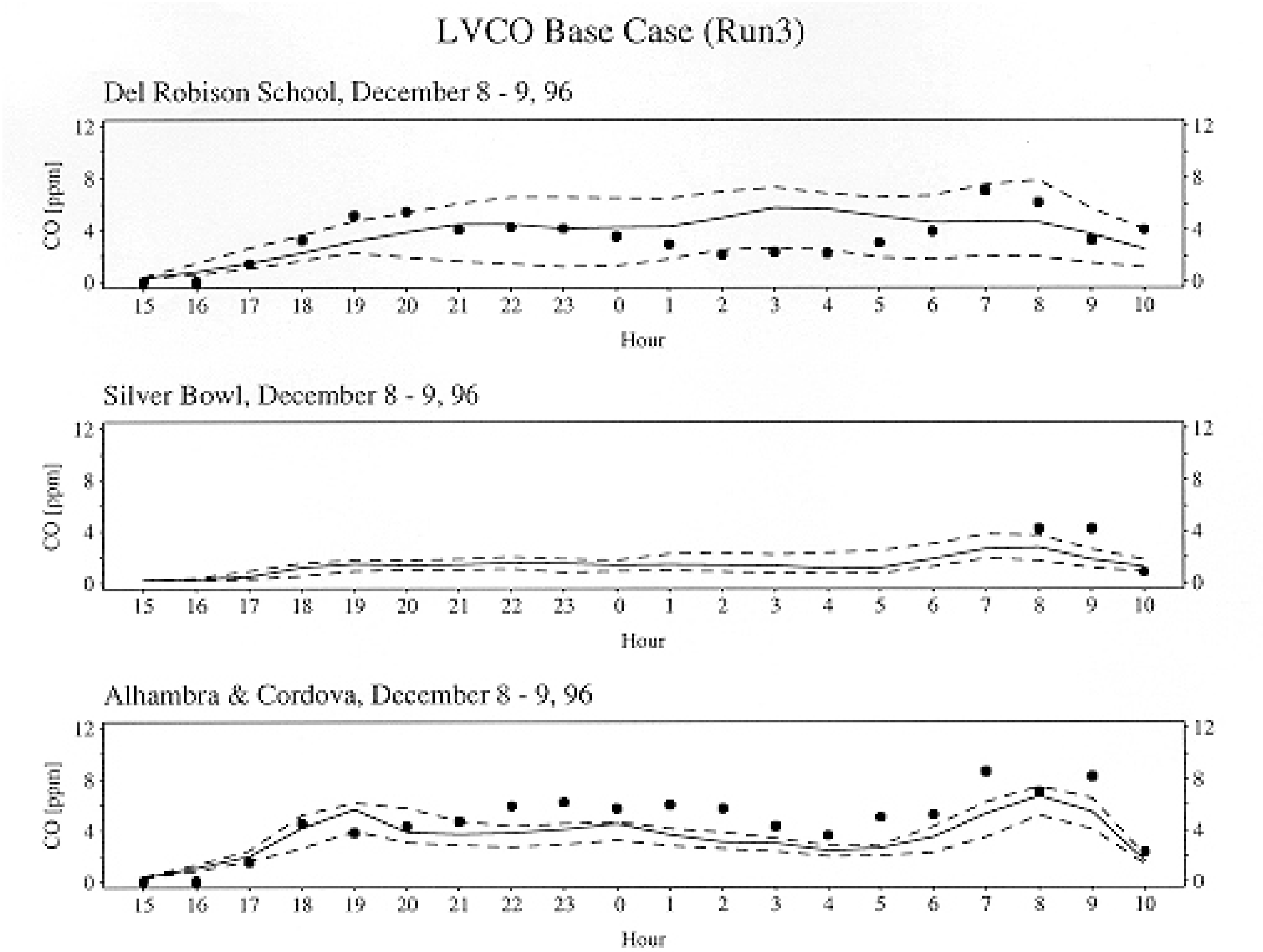


Figure 3-1. Continued.

Figure 3-1. Concluded.

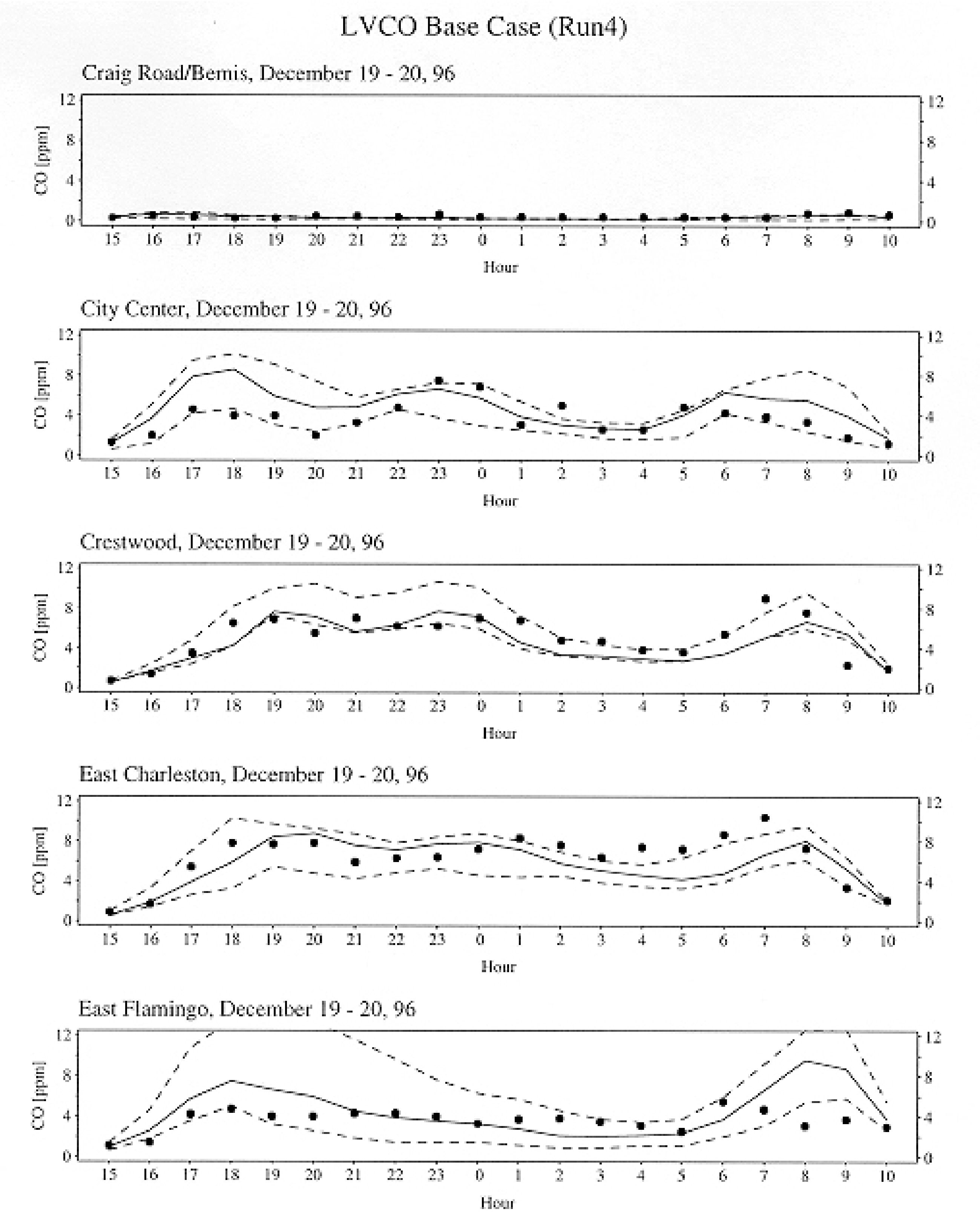

LVCO Base Case (Run4)
Craig Road/Bemis, December 19 - 20, 96
City Center, December 19 - 20, 96
Crestwood, December 19 - 20, 96
East Charleston, December 19 - 20, 96
East Flamingo, December 19 - 20, 96
CO [ppm]
Hour
0
4
8
12
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
8
9
10

Figure 3-2. Comparison of observed CO concentrations (•••) against UAM estimated CO concentrations (___) for December 19-20, Base Case.

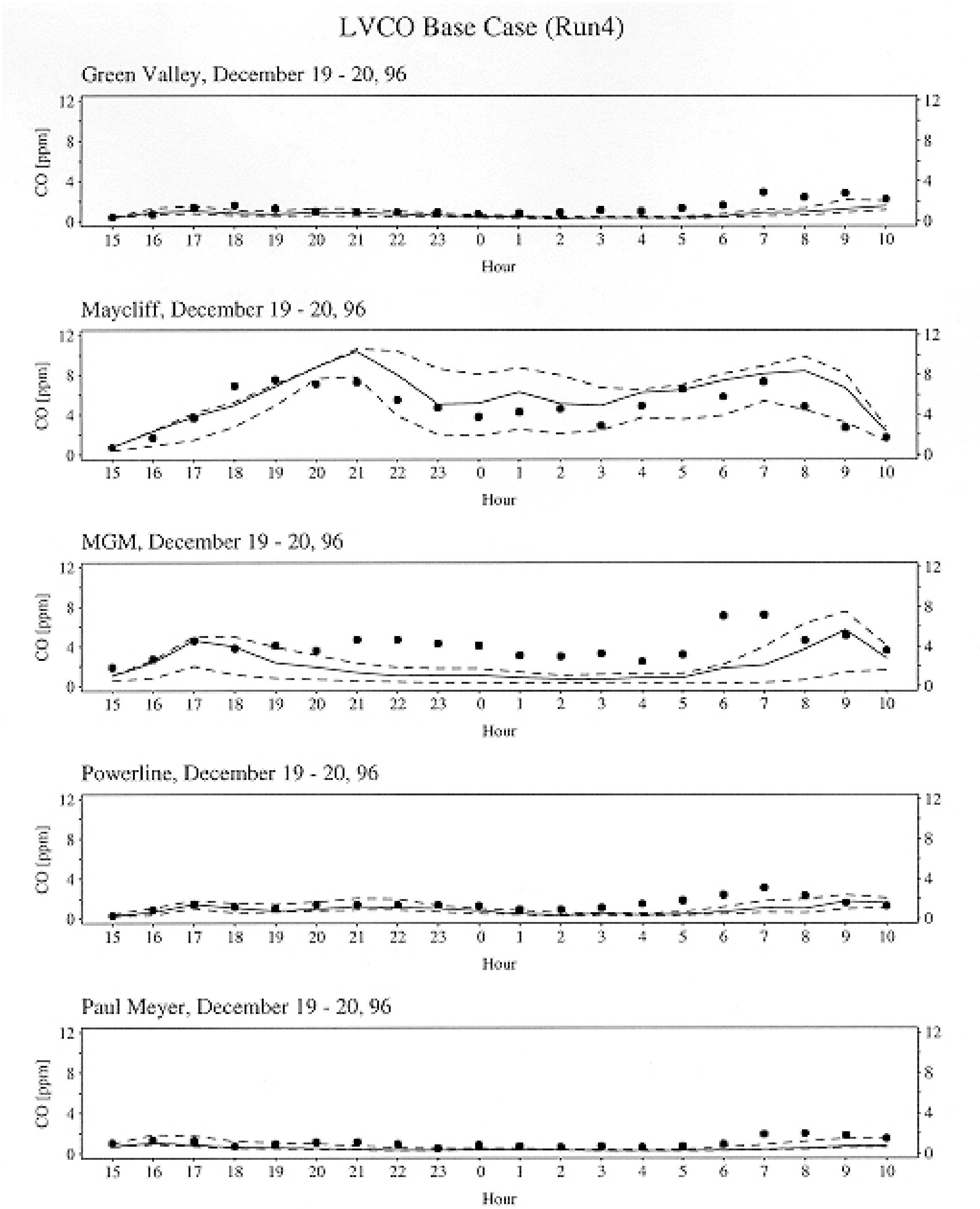

LVCO Base Case (Run4)
Green Valley, December 19 - 20, 96
Maycliff, December 19 - 20, 96
MGM, December 19 - 20, 96
Powerline, December 19 - 20, 96
Paul Meyer, December 19 - 20, 96
CO [ppm]
Hour
0
4
8
12
15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10

Figure 3-2. Continued.

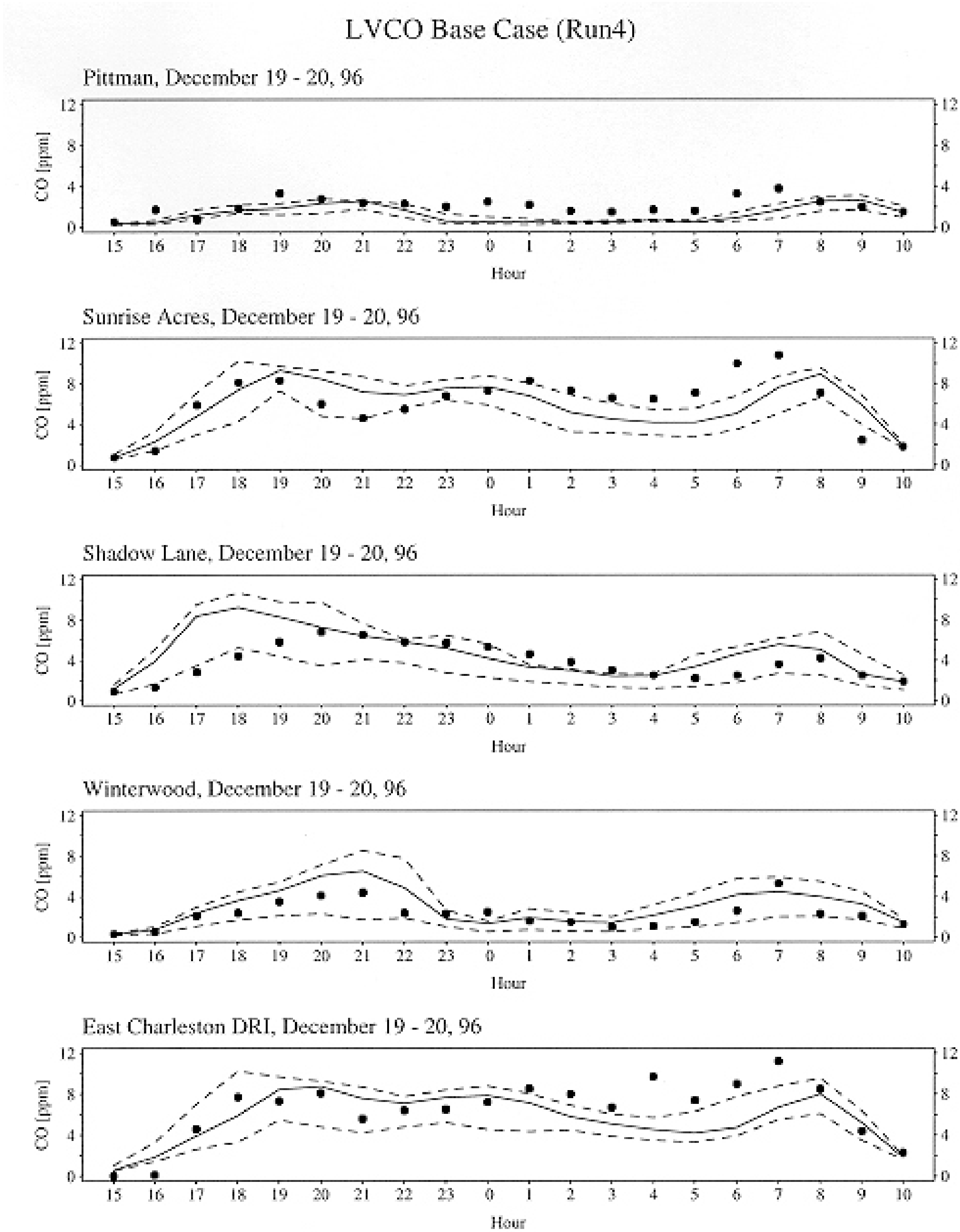

LVCO Base Case (Run4)
Pittman, December 19 - 20, 96
Sunrise Acres, December 19 - 20, 96
Shadow Lane, December 19 - 20, 96
Winterwood, December 19 - 20, 96
East Charleston DRI, December 19 - 20, 96
CO [ppm]
Hour
0
4
8
12
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
8
9
10

Figure 3-2. Continued.

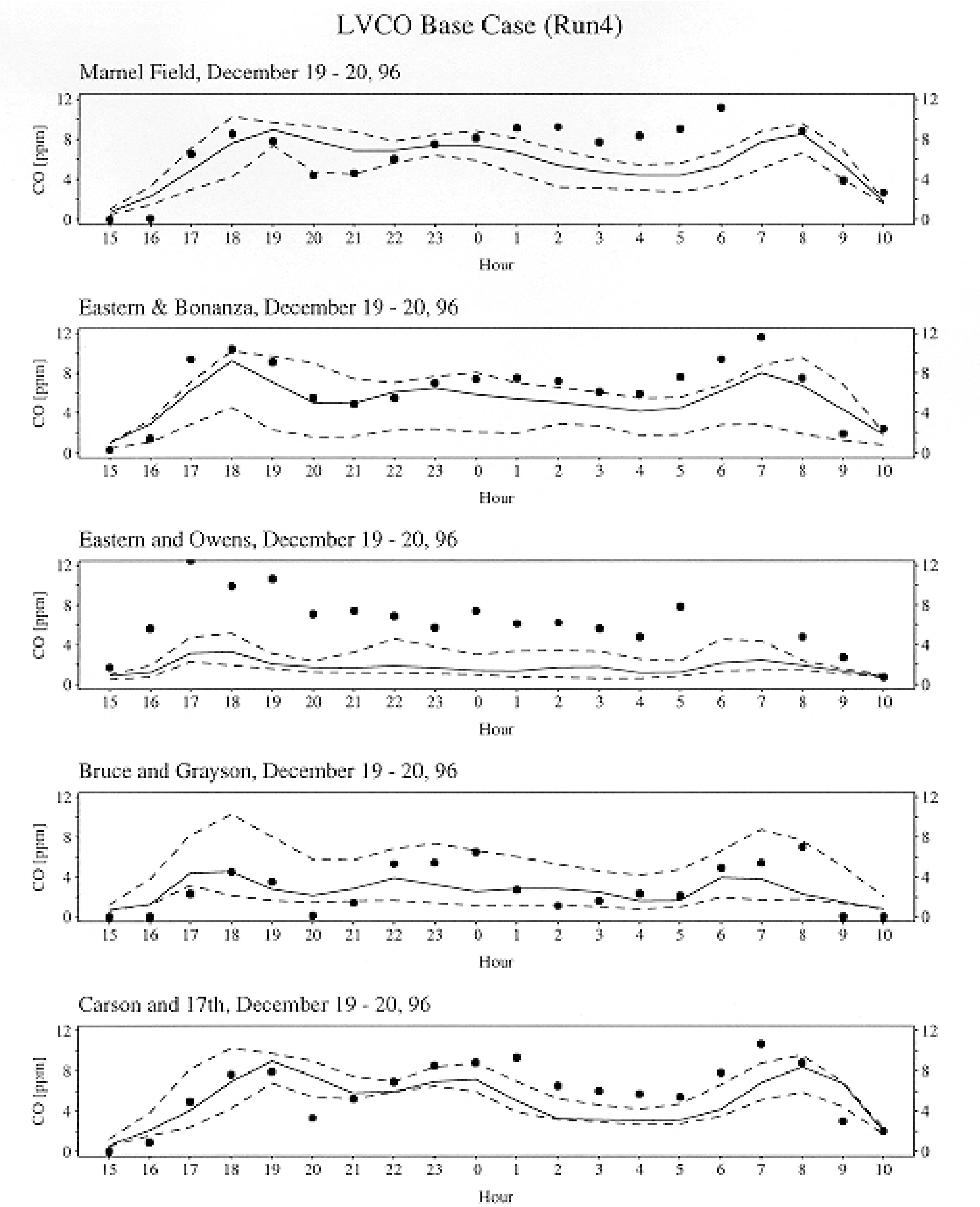
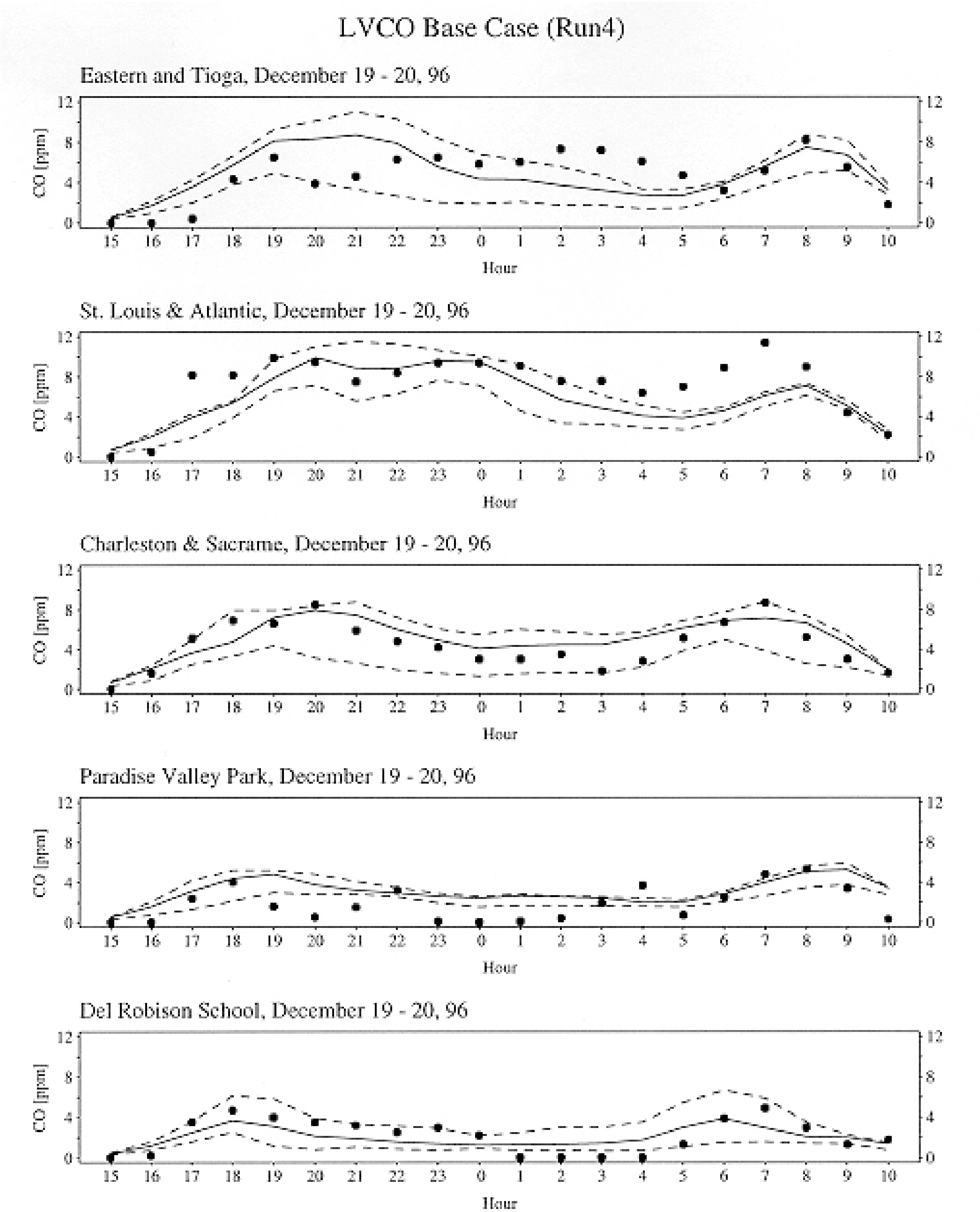

LVCO Base Case (Run4)
Marnel Field, December 19 - 20, 96
Eastern & Bonanza, December 19 - 20, 96
Eastern and Owens, December 19 - 20, 96
Bruce and Grayson, December 19 - 20, 96
Carson and 17th, December 19 - 20, 96
CO [ppm]
Hour
15 16 17 18 19 20 21 22 23 0 1 2 3 4 5 6 7 8 9 10
0 4 8 12

Figure 3-2. Continued.


LVCO Base Case (Run4)
Eastern and Tioga, December 19 - 20, 96
St. Louis & Atlantic, December 19 - 20, 96
Charleston & Sacrame, December 19 - 20, 96
Paradise Valley Park, December 19 - 20, 96
Del Robison School, December 19 - 20, 96
CO [ppm]
Hour
0
4
8
12
15
16
17
18
19
20
21
22
23
0
1
2
3
4
5
6
7
8
9
10

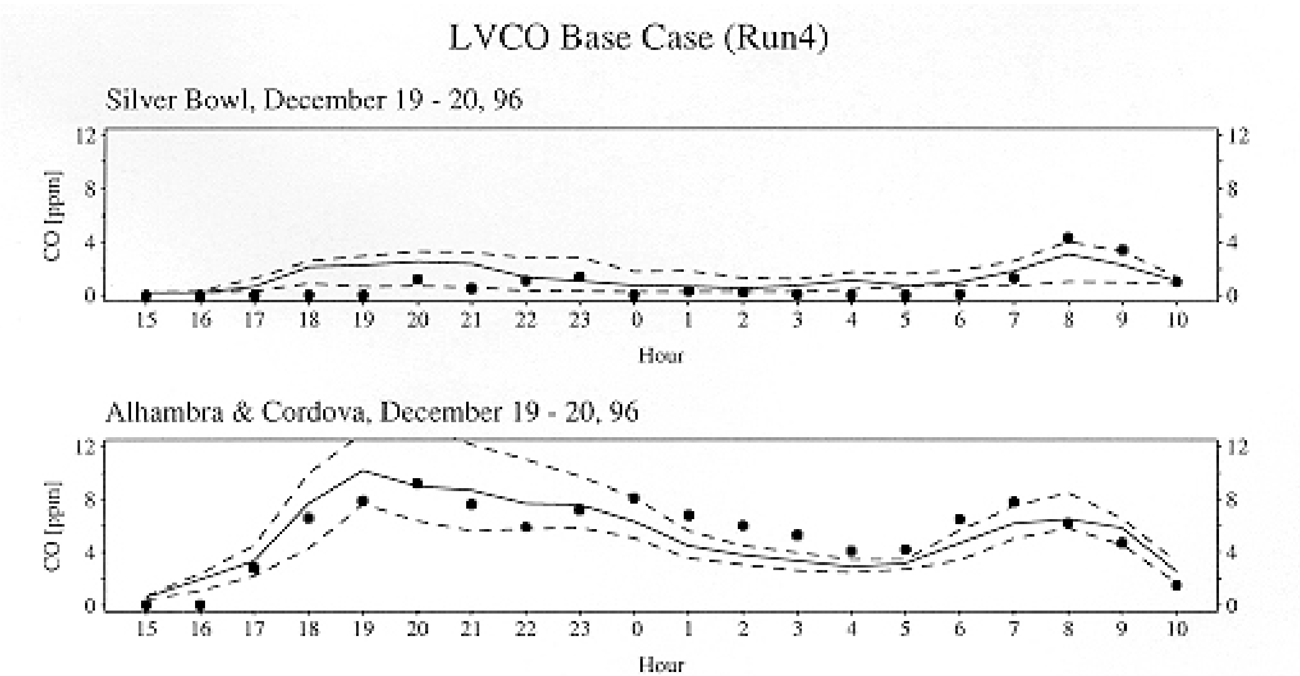


Figure 3-2. Continued.

Figure 3-2. Concluded.

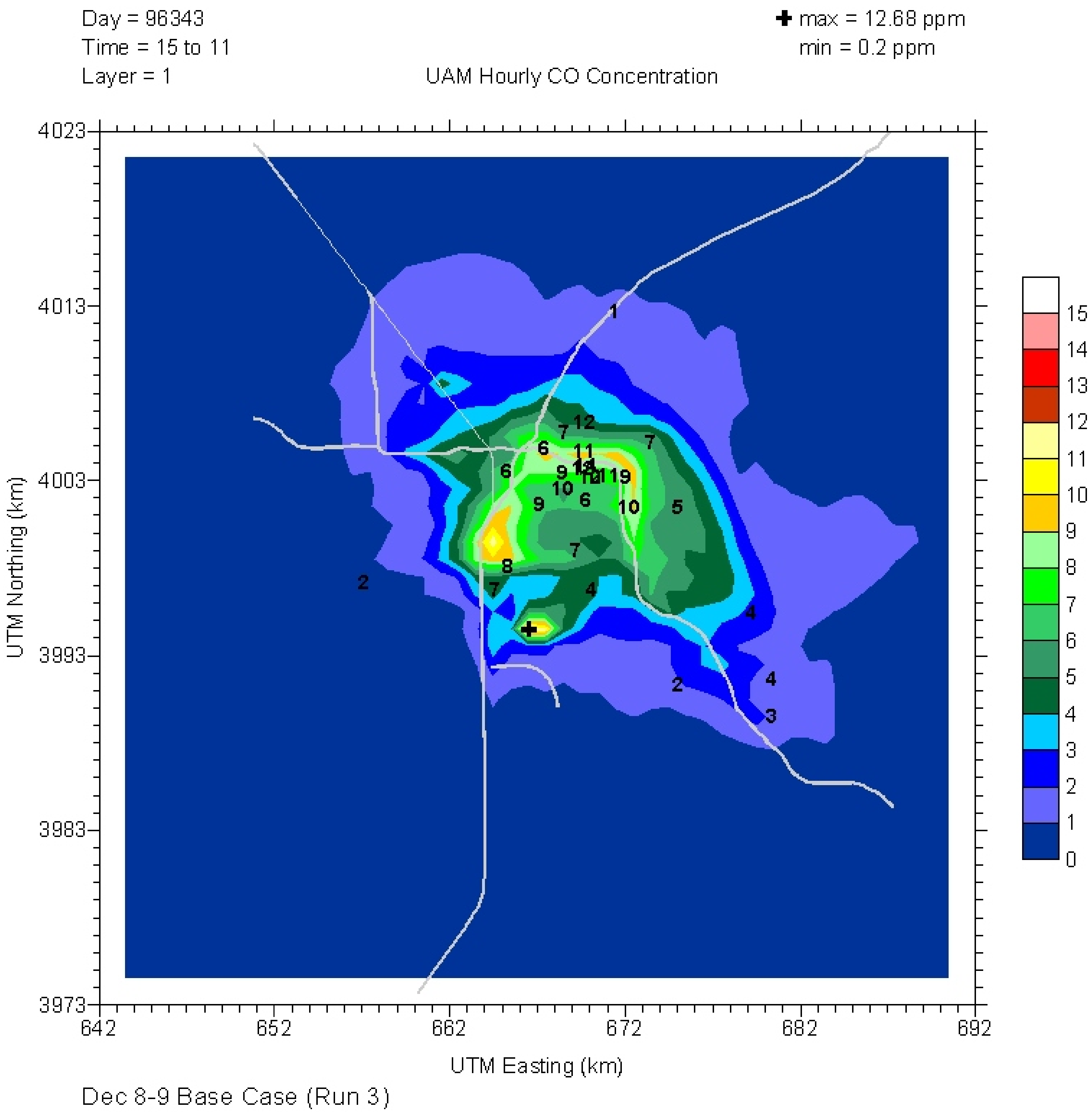

Day = 96343
Time = 15 to 11
Layer = 1
UAM Hourly CO Concentration
✚ max = 12.68 ppm
min = 0.2 ppm
UTM Northing (km)
UTM Easting (km)
4023
4013
4003
3993
3983
3973
642
652
662
672
682
692
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
Dec 8-9 Base Case (Run 3)

Figure 3-3. Spatial distribution of 1-hour maximum CO concentrations predicted for the December 8-9 Base Case.

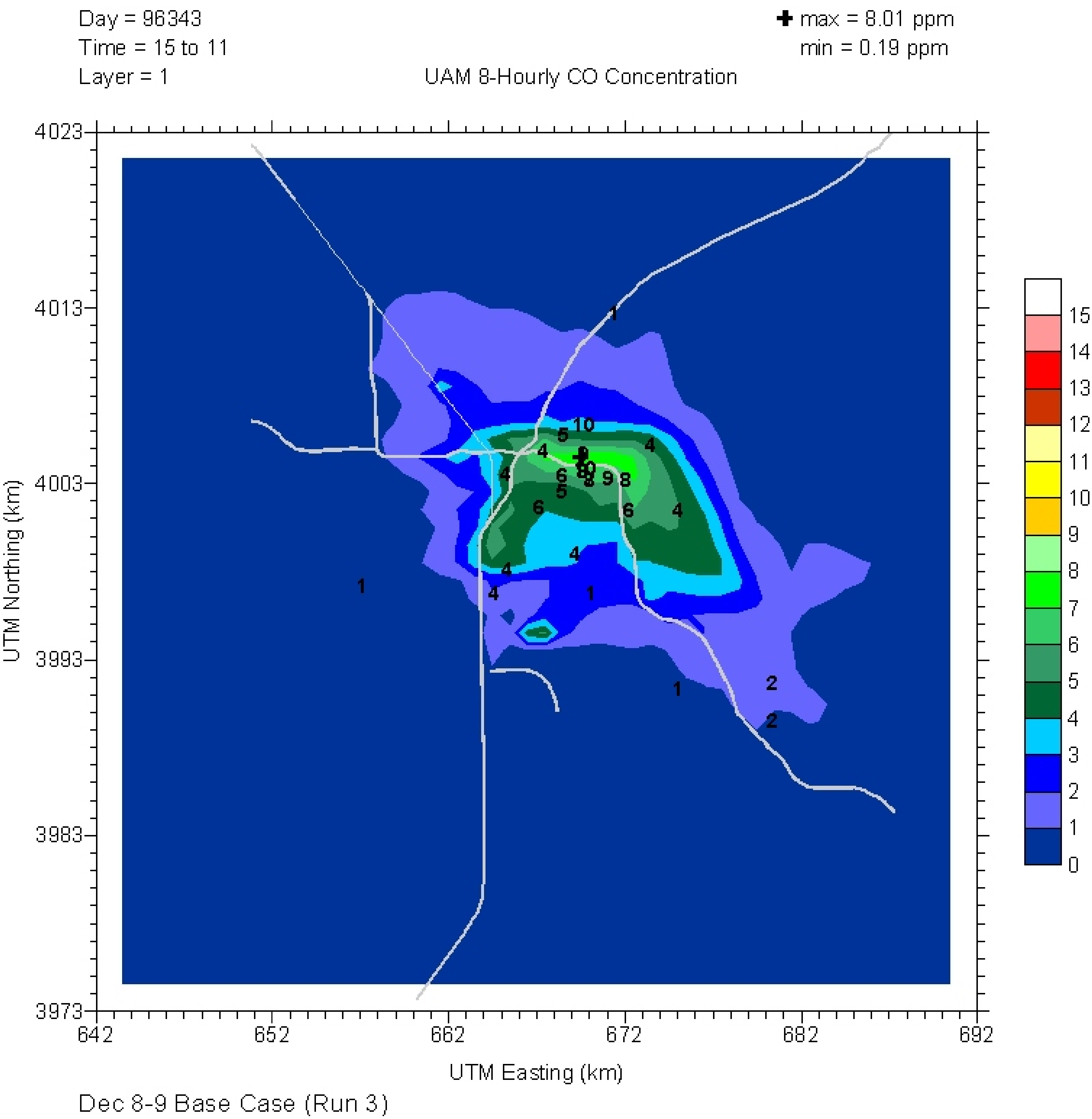


Figure 3-4. Spatial distribution of 8-hour maximum CO concentrations predicted for the December 8-9 Base Case.

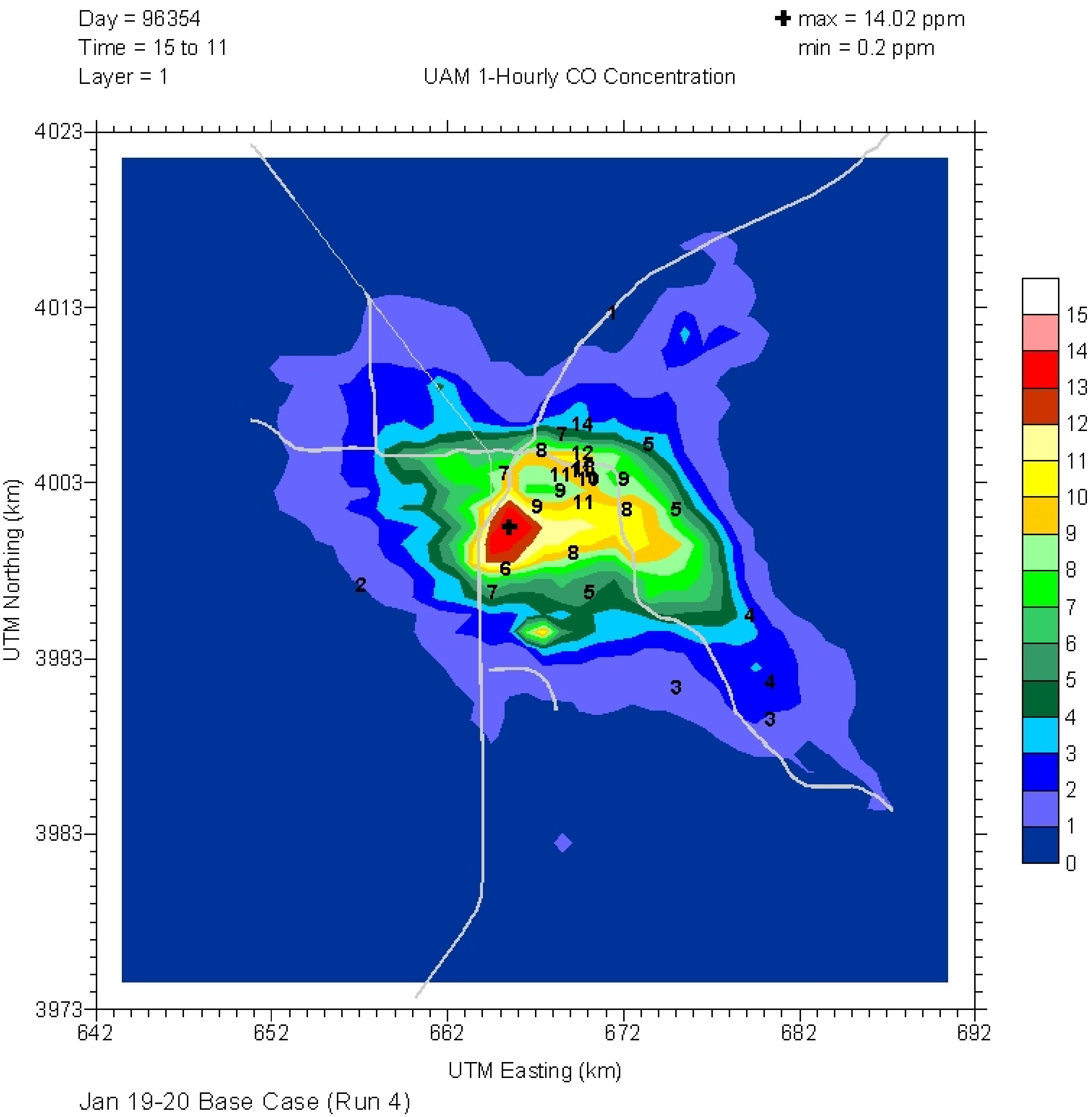


Figure 3-5. Spatial distribution of 1-hour maximum CO concentrations predicted for the December 19-20 Base Case.

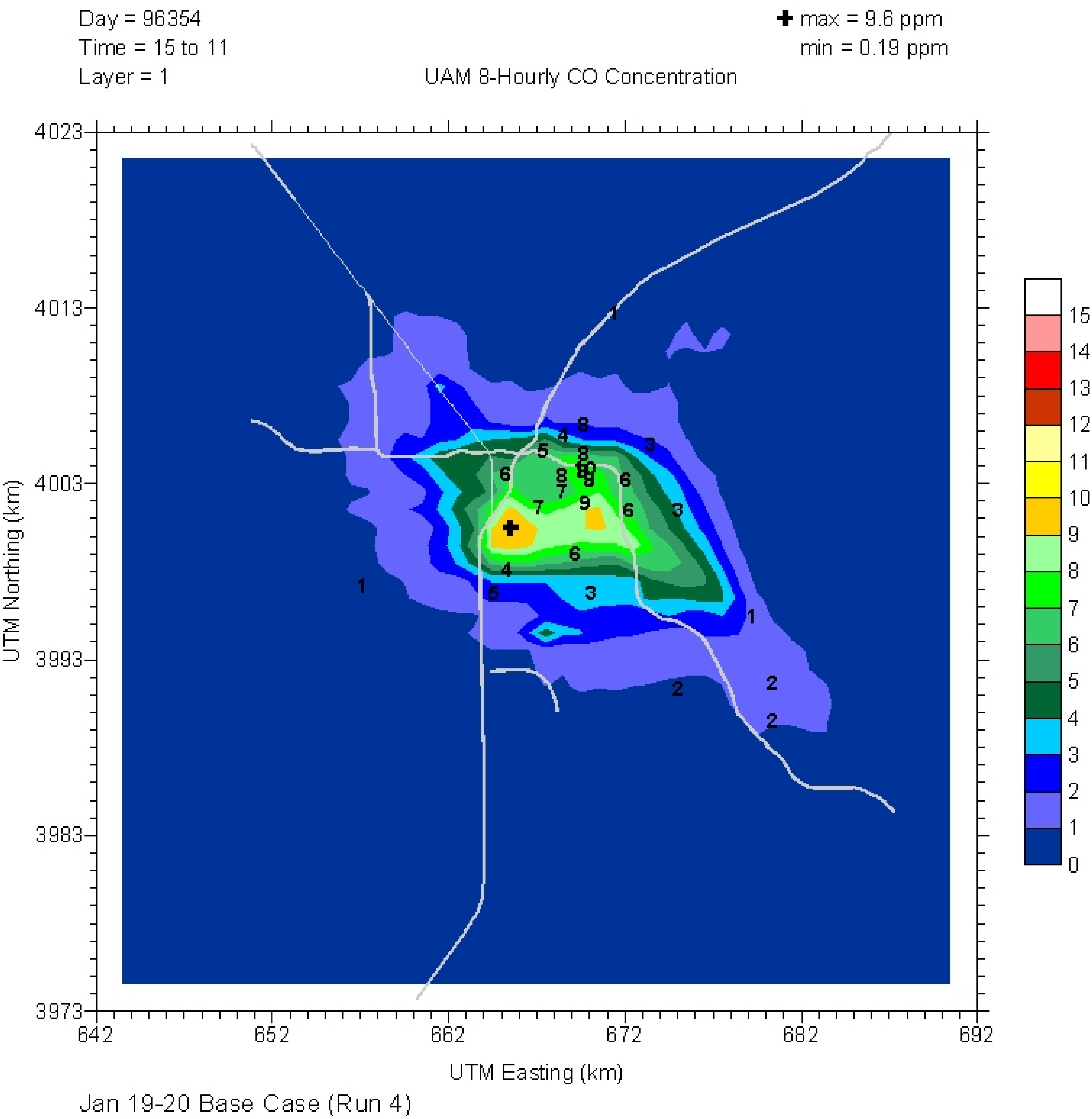


Figure 3-6. Spatial distribution of 8-hour maximum CO concentrations predicted for the December 19-20 Base Case.

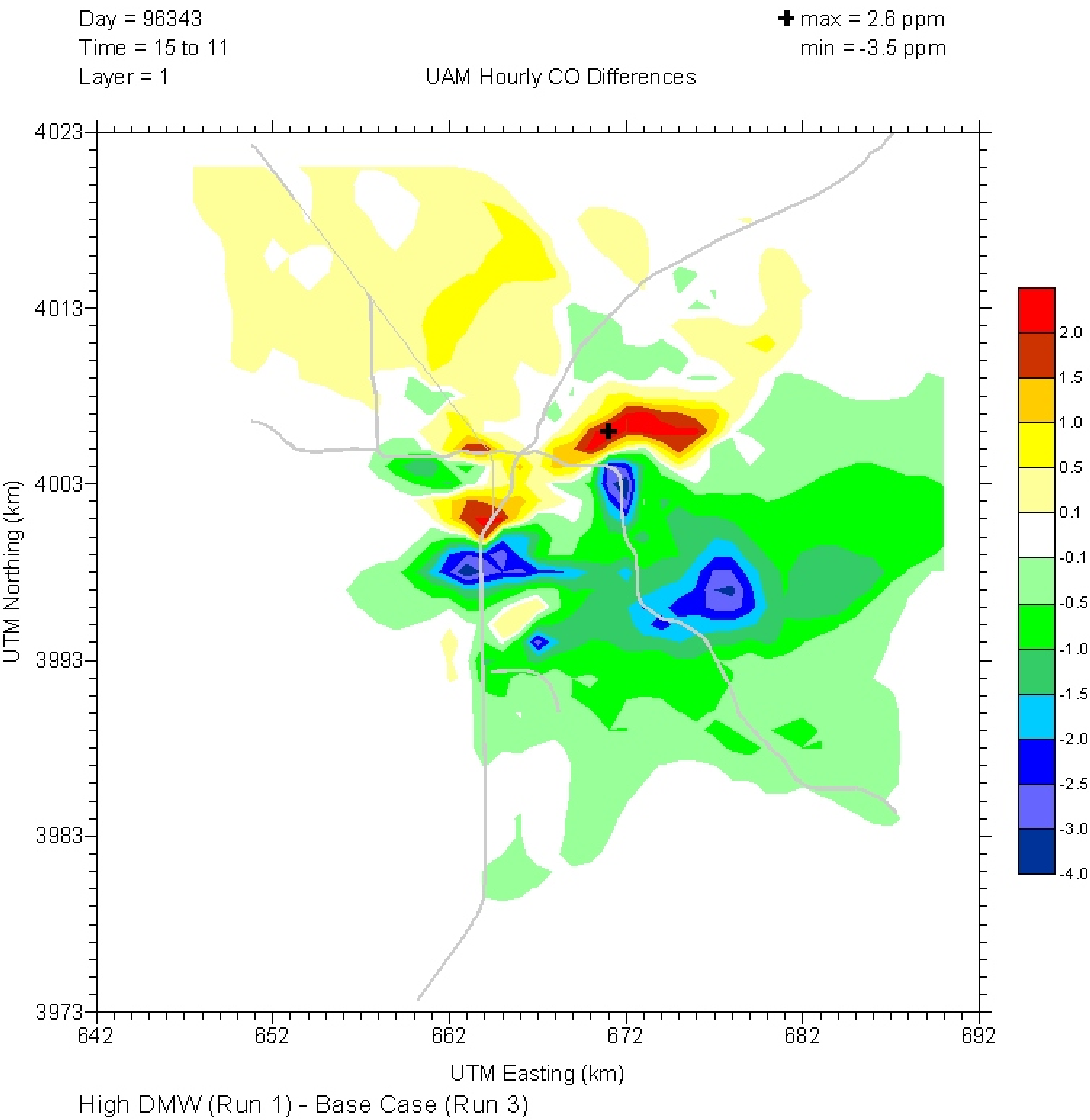


Figure 3-7. Differences in 1-hour maximum CO concentrations between the high DWM case and the Base Case for the December 8-9 episode (High DMW minus Base Case).

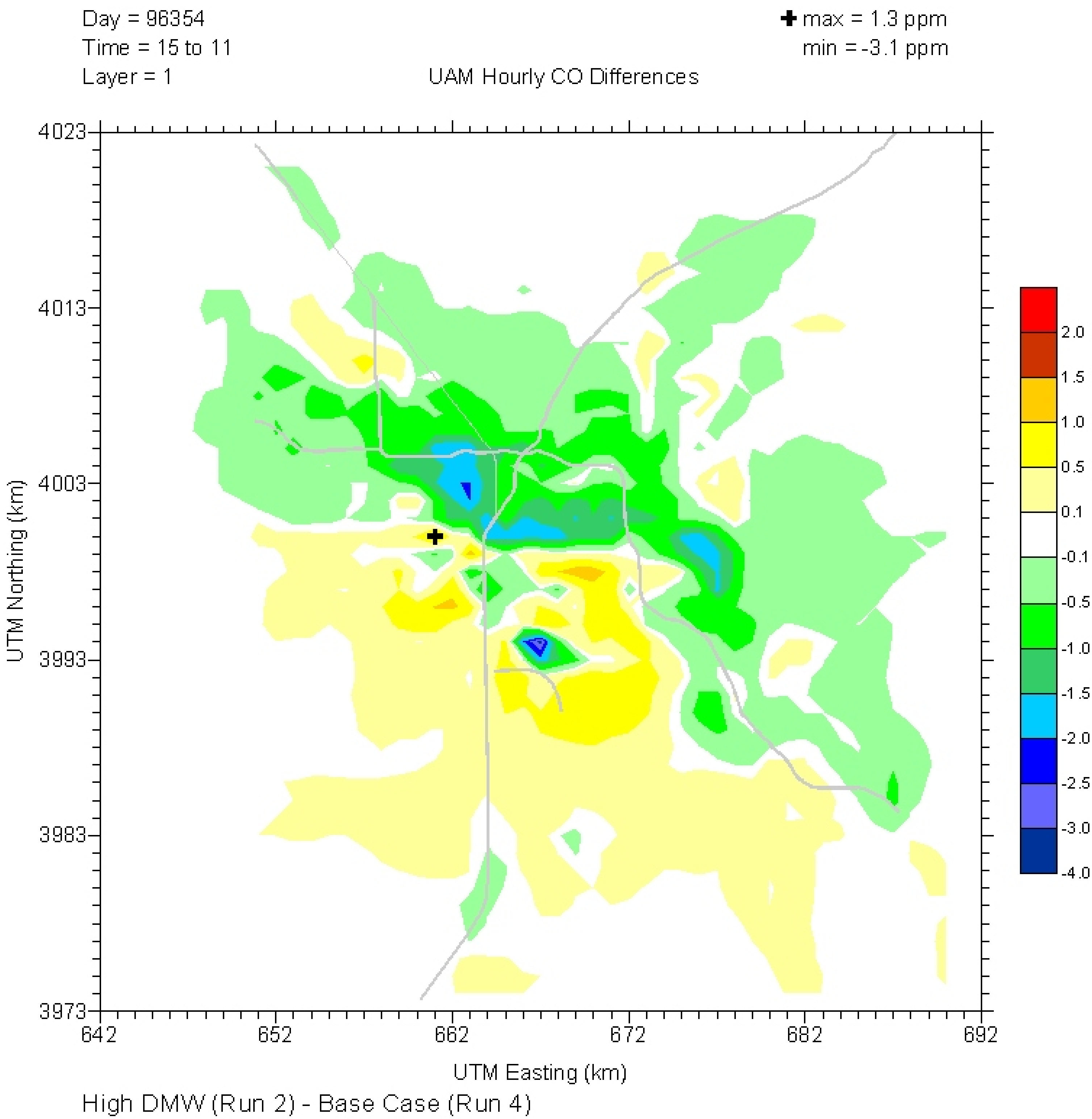


Figure 3-8. Differences in 1-hour maximum CO concentrations between the high DMW case and the Base Case for the December 19-20 episode (High DMW minus Base Case).

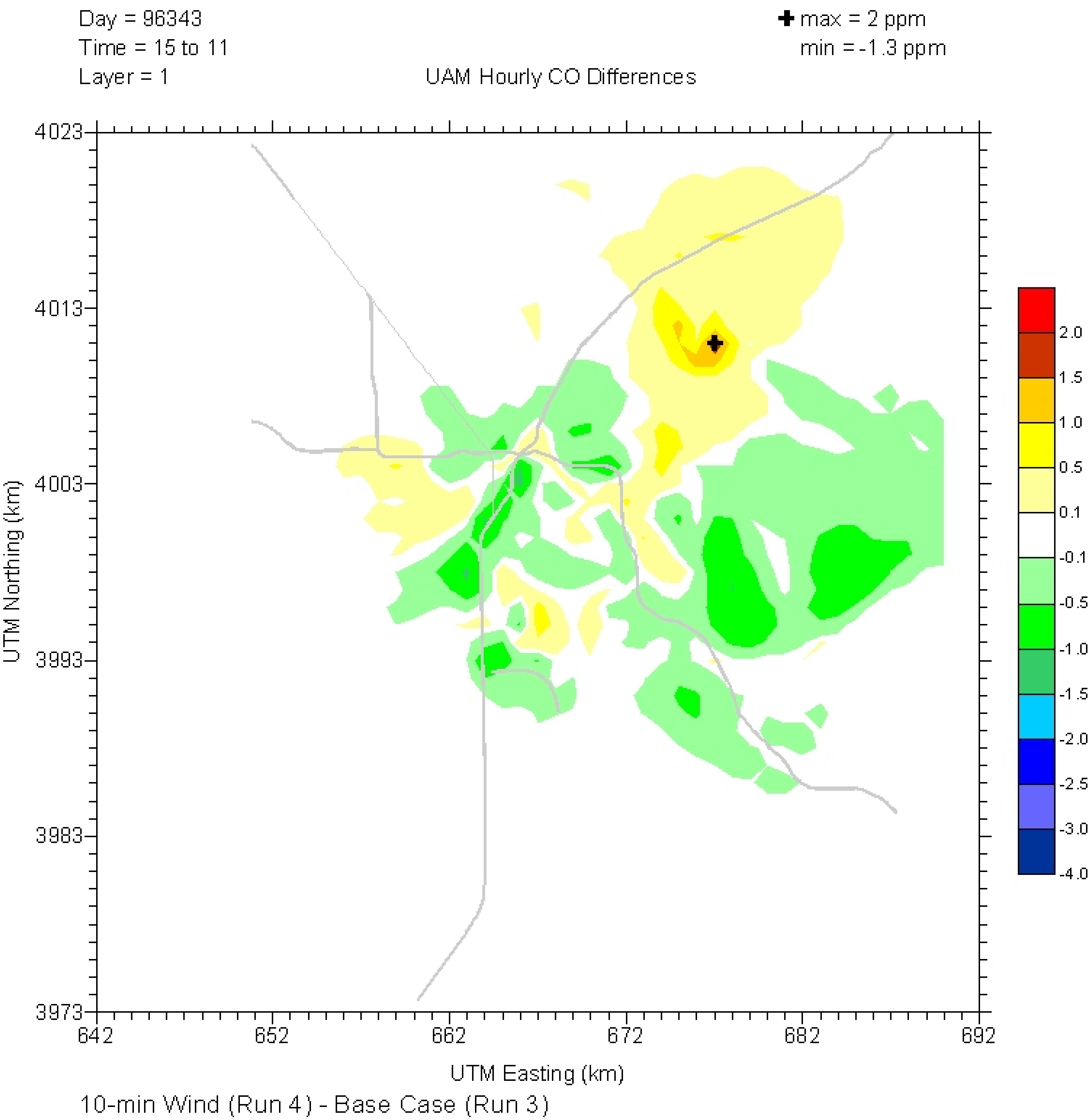


Figure 3-9. Differences in 1-hour maximum CO concentrations between the 10-minute wind case and the Base Case for the December 8-9 episode (0-minute minus Base Case).

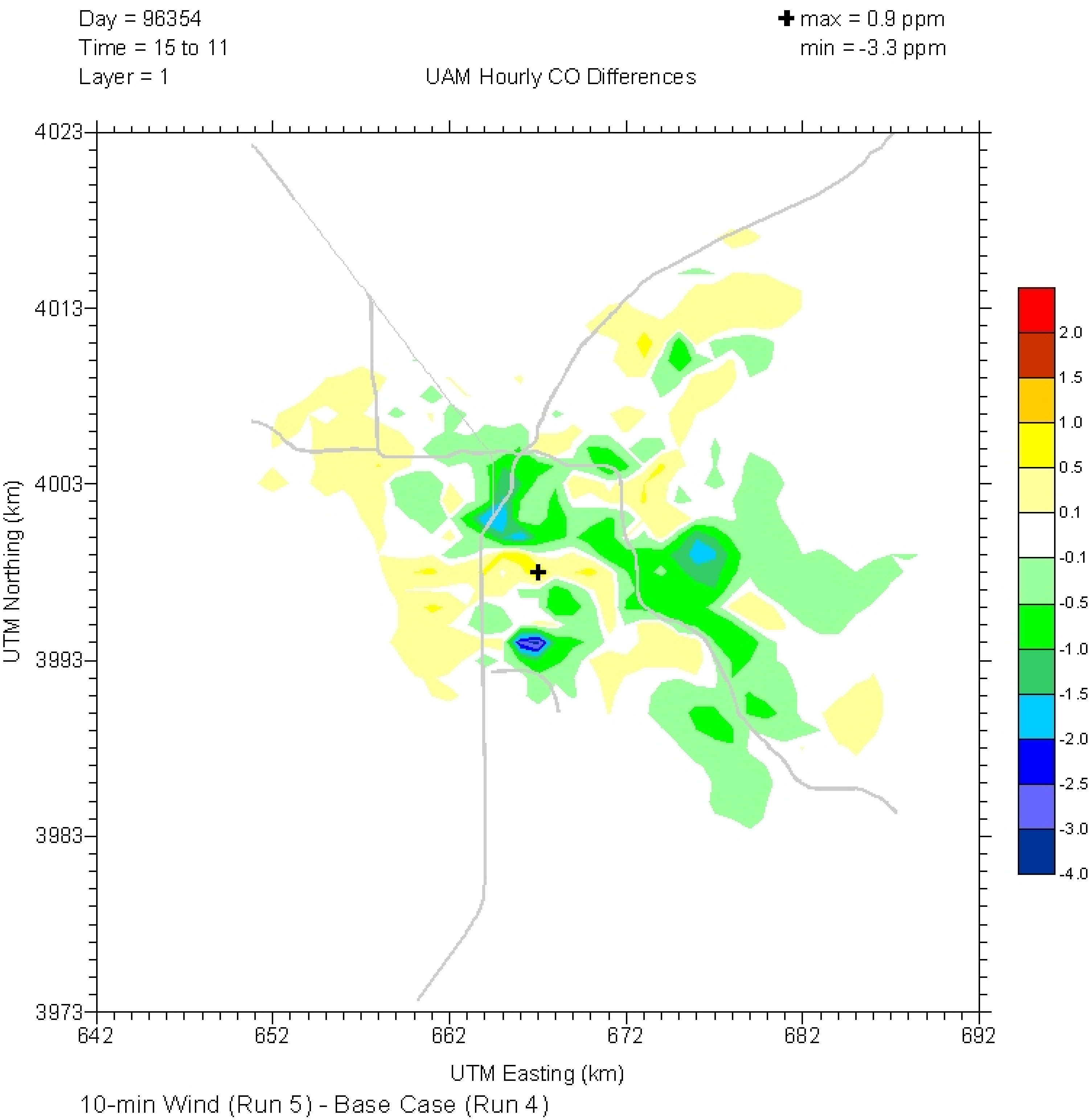


Figure 3-10. Difference in 1-hour maximum CO concentrations between the 10-minute wind case and the Base Case for the December 19-20 episode (10-minute wind minus Base Case).

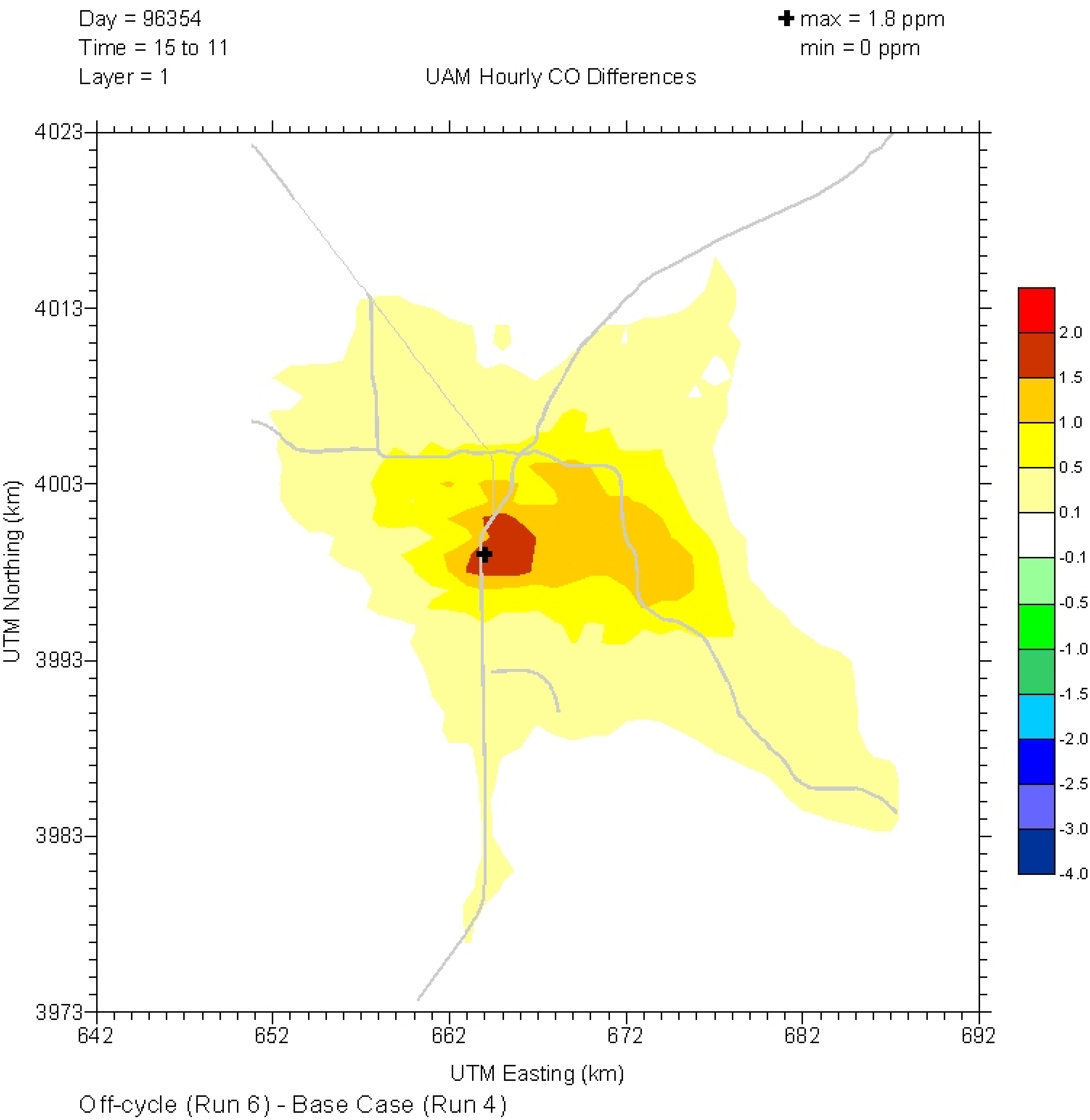


Figure 3-11. Difference in 1-hour maximum CO concentrations between the High Emission case and the Base Case for the December 19-20 episode (High Emission minus Base Case).

4. CONCLUSIONS

SUMMARY

The Phase II field study provided an improved database for characterizing the winter meteorological conditions in the LVV domain and the spatial distribution of CO concentrations. The improved database provided an opportunity to further assess the performance of the UAM model for CO in LVV. The findings from the Phase I modeling were used to configure the model for the Phase II modeling. For example, 10 vertical layers were selected based on our experience during Phase I modeling. The meteorological sensitivity tests were selected to evaluate the effects of high domain-mean winds and 10-minute winds on the model results. An emissions sensitivity test was conducted to evaluate the effect of increased “off-cycle” emissions from the vehicle fleet.

Overall, the model performance was much better for the December 8-9 and December 19-20, 1996 episodes simulated in Phase II than for the January 5-6, 1996 episode simulated in Phase I. The improvement is attributed to the availability of more surface and upper air meteorological data and better representation of morning emissions in the Phase II simulations. The normalized bias was within ±15 percent and the normalized error was within ± 30 percent for both episodes for the 8-hour concentrations. The model performance statistics were within the EPA CO guideline acceptance criteria for the December 8-9 episode, and close to the acceptable limits for the December 19-20 episode. The only statistical parameter not falling within an acceptable range is the error in timing of predicted peaks, which stray by 3-4 hours. The model predicted unsubstantiated maximum CO concentrations near McCarran airport and northwest of the Flamingo monitoring site for both episodes. These predictions were much higher than nearby microscale monitoring and historical measurements in the Strip area. Both the airport and the northern Strip are modeled as high CO emission sources that lead to high predicted CO concentrations under stagnant conditions. The uncertainty in the quantity and spatial distribution of CO emissions in these areas needs to be examined.

The results from the high domain mean winds and 10-minute winds model simulations suggest that the UAM-predicted CO concentrations in the LVV are not particularly sensitive to these modifications for the primary episode of December 19-20. The secondary episode (December 8-9) shows slightly more sensitivity, and that is attributed to the more variable meteorology that characterized valley conditions during that episode. Results from the meteorological sensitivity tests agree with the conclusions from the Phase I modeling that UAM performance issues in LVV are mainly driven by uncertainties in emissions. The main reason for the lack of sensitivity to meteorological inputs revolves around the lack of significant transport across the LVV during the stagnant conditions. The domain mean winds only affect the wind fields in the outlying areas and aloft, which do not have significant effect on the surface winds or the estimated CO concentrations in the highly monitored central area of the LVV during December 19-20. In theory, the transport and dispersion of CO under light wind conditions can be more accurately simulated with 10-minute average winds than hourly average winds. The sensitivity results suggest that the hourly winds are so light and variable that the effect of 10-minute winds on predicted CO concentrations is minimal for this application.

The simulated increase in "off-cycle" motor vehicle emissions caused a 15 percent increase in the hourly CO emissions for both episodes. The higher emission rates resulted in improved model performance for the December 8-9 episode, and mostly improved model performance for the December 19-20 episode. The base case emissions for the December 8-9 episode were significantly lower (by 29 percent) than those for the December 19-20 episode, which may explain why the model results responded favorably for the December 8-9 simulation. These results also suggests that emissions for the December 8-9 episode may have been underestimated for the base case. As noted elsewhere in this report, CO emissions are also likely under-estimated due to the use of MOBILE5a and the non-road mobile emissions under-predictions.

REMAINING ISSUES AND FUTURE WORK

There are two basic modeling issues remaining from the analyses reported here that must be addressed in follow on work currently planned for summer 1998. The first is the fact that the UAM modeling reported for Phase II is based upon what are officially non-exceedance episodes (although at least one non-standard portable CO monitors measured 8-hour CO above the NAAQS). There is continuing dialog between Clark County and EPA Region IX about the appropriateness of scaling the Phase II episodes to the historical design day peak of 10.2 ppm. On one hand, it appears that the overall CO pattern observed in the Phase II episodes reported here agree fairly closely with the conceptual model of CO buildup in the LVV, so that the mechanisms are similar (if not identical) to historical conditions. On the other hand, since they are not exceedance events, some factor (e.g., warmer than usual temperatures, changed emission patterns, marginally more venting aloft, etc.) has played a role in inhibiting CO buildup at the official sites, and thus the possibility exists that these episodes do not fully represent the mechanisms at work during the worst conditions. This issue could be downplayed by demonstrating any control plans on both Phase II modeling episodes and the design day episode in Phase I.

The second issue concerns a problem with the modeling itself, namely the unsubstantiated peak predicted CO in the area of Spring Mountain Road, I-15, and the Las Vegas Boulevard interchange area. This was seen in both Phase I and II UAM episodes, and raises additional questions that must be addressed before future year control demonstration modeling can be carried out. These include:

- What exactly is the cause of the high CO emissions in this area, is it a result of deficiencies in other models (e.g., TRANPLAN, MOBILE, DTIM), or is it real?
- If it is real, and the traffic models are replicated this phenomenon accurately, why haven't current and historical monitors in the area indicated some sign of the resulting CO plume?
- Should UAM under-predictions be scaled up to observed peak CO concentrations in East Charleston area, in disregard of the unpaired peak CO predictions near Spring Mountain Road (which will increase this apparent overprediction even more)?

In an attempt to answer the first question, we looked into traffic volume estimates from TRANPLAN for the series of thoroughfare and connector links in the area of Spring Mountain Road, I-15, and Las Vegas Boulevard. Unreasonably high daily traffic volumes were found on several connector ramps. Since TRANPLAN works to conserve total number of vehicles on the traffic network, the higher volume leads to lower vehicle speed. Hourly traffic activity profiles are applied to the daily volumes in DTIM, which increase VMT even more during peak hours. Taken together, the high volumes, low speeds, and peak activity hours can result in much higher CO emissions estimates than actually occur.

The UAM CO modeling reported here was undertaken at the time the Regional Transportation Commission was initiating a rather substantive revision to TRANPLAN to update current and future year projections of the LVV traffic network. Therefore, our mobile source emissions modeling utilized output from an older version of TRANPLAN that may not have accurately described 1996 traffic volumes or contained all links or street/highway improvements. However, it was unclear how these estimates could be realistically yet simply adjusted for these UAM runs and still conserve VMT in the area.

Model performance surrounding the high unpaired peak predictions described above and general underpredictions in the East Charleston area has raised the issue of scaling model results to observed peak CO concentrations. During Phase II modeling, a number of options were suggested by the APCD (see letter from Naylor to S. Bohning, U.S. EPA, Region IX, May 1, 1997). In discussing such approaches with EPA Region IX, there was concern that the need for scaling simply masks poor UAM performance, which derives from emissions uncertainties as well as a poor linkage between emissions and resulting CO prediction patterns. In principle, if the high CO in the area of Spring Mountain Road can be explained by inaccurate traffic parameters in TRANPLAN, then either (1) UAM base case could be rerun using corrected VMT and mobile emissions (more technically defensible), or (2) the CO cloud in that area would be ignored; in either case, scaling of base UAM results could then be undertaken. Scaling of results would be hard to justify if the cause of the high CO cannot be linked to any obvious errors in mobile emissions. In that case, analysis of future-year controls would focus on reducing the unpaired peak (high predictions near I-15 and Spring Mountain Road vs. high measurements in the East Charleston area) to below the NAAQS.

In follow-on work, an updated (yet still interim) version of the TRANPLAN model will be used as the basis for redefining a new mobile source emission inventory[3]. This will likely also include interim revisions to the MOBILE5 model, and updates to DTIM. New UAM base case runs will be performed and analyzed; based upon model performance, decisions will be made at that time regarding the necessity for scaling UAM results. Then future year modeling will commence, with UAM run for various control strategy scenarios. Once final versions (1140TAZ) of TRANPLAN are available toward the end of 1998, base and future year analyses will be repeated, and a final control strategy demonstration completed.

[3] This interim revision of TRANPLAN is designated as “751TAZ”. The final TRANPLAN will be “1140TAZ”.

The basis of current thinking on control strategies and future year maintenance of CO NAAQS in Clark County rests on the idea of defining sub-regional emission budgets for the LVV. The idea is based upon the fact that a few localized heavy emission areas are seen (both via monitoring and modeling) to contribute a majority of CO in problem areas in valley. It is not reasonable to place a control burden on the entire valley by specifying a single basin-wide CO budget, since the vast majority of valley area is not contributing to these small problem areas. It is much more reasonable to control certain key source areas, such as providing for local traffic improvements. This allows for separate emission budgets to be defined for outer areas, which in turn would allow further growth without endangering conformity of the CO NAAQS.

Modeling is key to defining appropriate sub-regional emission budgets. The problem is that the modeling must be sufficiently robust to ensure that key sources and subsequent dispersion are depicted correctly. We see the use of model "tracers" as the major tool in the process of developing emission budgets. The UAM has been modified to track photochemical precursors to apportion ozone air quality to various sources by geographic region and/or source type. This model is known as the Ozone Tool, and was developed for the South Coast Air Quality Management District in California (Yarwood et al., 1996). It is fairly straightforward to utilize this model for inert CO. While modeling CO with UAM is quick, and several runs for each sub-area could be performed separately to obtain the same information, the Ozone Tool allows this process to be performed in just one run, by simply supplying the model with a source area map defined by regions of grid cells. In this way, any number of source regions, even down to each model individual grid cell, could be treated. Of coarse, caution should be taken in over-defining source regions, since the accuracy of emissions in a given region tends to deteriorate as the region size approaches a single cell on the order of 1 km.

Appendix B presents an example exercise with the UAM Ozone Tool, in which 8 source areas were defined, and CO emissions from each were tracked and tallied for each grid cell to develop an example source-area budget for peak CO in the traditional problem area (East Charleston and Sunrise Acres). The follow-on base case revisions and future year control plan applications with UAM and the Ozone Tool will be described in a follow-on report. It is intended that the follow-on work will provide a basis for Clark County to develop their CO SIP in 1999.

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APPENDIX A

Final Report

THE LAS VEGAS VALLEY CARBON MONOXIDE URBAN AIRSHED MODEL UPDATE PROJECT – PHASE I: INITIAL UAM APPLICATION

ENVIRON

MEMORANDUM

To: Clete Kus, Principal Planner, Clark County Department of Comprehensive Planning
Las Vegas CO Update Project Oversight Committee Members

From: Chris Emery, Jeremy Heiken, David Souten

Date: December 20, 1996

cc: Scott Bohning, USEPA, Region IX
Paul Roberts, Fred Lurmann (STI)
Dick Egami (DRI)

Subject: Phase I draft final report

This technical memorandum presents a final report on activities performed under Phase I of the Las Vegas Valley (LVV) Carbon Monoxide Urban Airshed Model Update Project. The text presented herein will also be included in the project final report upon completion of Phase II. Information on historical background, study objectives, project overview, and project organization is provided in the Phase I modeling protocol. The Introduction section summarizes the Phase I technical approach, and describes sources of emissions, air quality, and meteorological data. The remainder of this memorandum provides descriptions of the Urban Airshed Model (UAM) domain grid, Phase I episode selection, model input development, and UAM results for a base case simulation and several sensitivity tests.

INTRODUCTION

Overview of Technical Approach

The study objectives are to be met through the completion of several tasks under two project phases. In Phase I, all necessary UAM inputs were developed for a winter 1995/96 base case carbon monoxide (CO) episode. A review of UAM performance with special regard to data gaps, uncertainties, and limitations, has shaped the implementation of a special field monitoring program under Phase II during the 1996/97 winter season. A new modeling episode will be selected from the Phase II period, and the routine and special field data collected will be used for new UAM and CAL3QHC microscale (or "hotspot") modeling. Finally, impacts from several future year emissions estimates will be modeled in Phase II. A list of specific tasks followed under Phase I is listed below, along with a brief description of activities performed. The procedures followed in executing these tasks are described in more detail in the following sections.

- Develop a Modeling Protocol: Develop a protocol to describe in detail the procedures to be followed in all facets of UAM CO modeling; submitted to the U.S. EPA Region IX for review and approval.

- Baseline Emissions Inventory: Calculate the 1996 annual and seasonal CO emissions inventories for on-road mobile, area, and point sources.

- Episode Selection: Compile and evaluate all available meteorological and CO air quality data from the winter 1995-96 to identify a CO episode for Phase I modeling.

- Prepare Meteorological/Air Quality Files: Develop DWM meteorological and air quality files in UAM format for each episode day.

- Review Existing UAM Input Files: Review and evaluate the methodology used to develop UAM input files that previously existed for the December 7-8 1990 episode, and examine the files for errors/omissions, accuracy, and representativeness of the Las Vegas Valley for the given conditions.

- Prepare Episode Day Emission Inventory: Develop the episode day gridded emissions inventory from the 1995 base year inventory developed under Task 2.1.

- Data Quality Assurance and Model Diagnostic Analysis: Review all UAM input emissions, meteorological, and initial/boundary fields prior to all UAM simulations. Perform diagnostic sensitivity tests to understand UAM response to changes in various parameters and input files known to be the most influential on CO predictions. Evaluate UAM performance in predicting CO throughout the Las Vegas modeling domain using statistical, graphical, and process-oriented methods. Assess the adequacy of the existing

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monitoring network to ensure that a reasonable degree of confidence may be placed on the resulting statistics. Investigate potential improvements to both meteorological fields and to UAM itself that better characterize the stagnation conditions associated with high CO events in the LVV.

- Project Reporting and Documentation: Prepare monthly progress reports, present status reports on current activities to the Project Oversight Committee and the Air Quality Planning Committee, prepare a report for the Regional Transportation Commission Executive Advisory Committee after the completion of the on-road mobile source inventory and episode day emissions inventory, and document all Phase I activities in a draft and final Phase I report.

Air Quality, Meteorological, and Emissions Database

Ambient LVV surface CO air quality and meteorological data (wind speed/direction and temperature) are routinely logged by a network of monitoring stations operated by the Clark County Health District, Air Pollution Control Division (APCD). This agency is also responsible for performing quality assurance checks on the data, and updating and maintaining a publicly-accessible database. Table 1 presents a list of APCD monitoring stations operating during the winter of 1995/96, along with types of data recorded, coordinates, and probe heights.

Routine surface hourly meteorological data are also available from Nellis Air Force Base and McCarran International Airport. These reports are typically instantaneous observations taken 0-10 minutes before each hour, and therefore do not provide information on conditions at these two sites over an entire hour. Airport data are reported by the National Weather Service to the National Climatic Data Center. The only routine upper air meteorological data available for the area is from the Desert Rock Airport rawinsonde site located about 100 km northwest of downtown Las Vegas. This site is operated by the National Weather Service and supplies tropospheric temperature, humidity and wind soundings every 12 hours. All National Weather Service data were procured from the Desert Research Institute (DRI), Western Regional Climate Center. Table 1 indicates coordinates of the McCarran and Nellis monitoring locations.

During January 1994, DRI conducted a tracer experiment to investigate transport patterns during conditions of high stagnation and CO buildup. The existing APCD network was augmented with several more meteorological sites as well as tethersonde measurements near the East Charleston monitoring site to obtain shallow vertical soundings of temperature and wind. This database was obtained from DRI, and the tethersonde data were used in Phase I of the current study for modeling the winter 1995/96 CO episode.

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Table 1. Phase I Las Vegas Valley monitors, indicating location, and meteorological vs. CO measurements.

Site	Location (km)		Measurement Data	
	UTM East	UTM North	Met	CO
East Charleston (EC)	669.985	4003.318	✔	✔
Proximity (PX)	near EC		✔	✔
Microscale (MS)	near EC			✔
East Bonanza/City Center (CC)	667.440	4004.817	✔	✔
East Sahara/Maycliff (MC)	672.246	4001.458	✔	✔
Winterwood (WW)	675.025	4001.446	✔	✔
Powerline (PL)	680.431	3989.445	✔	✔
Craig Road (BS)	671.439	4012.654	✔	✔
East Flamingo (FL)	665.386	3998.034	✔	✔
Shadow Lane (SL)	665.304	4003.473	✔	✔
E. Vegas Valley/Dime III (DM)	675.429	4000.654	✔	
McDaniel P.O., NLV (LM)	668.794	4007.136	✔	
Paul Meyer (PM)	657.191	3997.118	✔	✔
Pittman (PT)	680.390	3991.640	✔	✔
Variety School (VS)	669.675	4003.630	✔	✔
West Alta/Walter Johnson (WJ)	656.383	4004.017	✔	
NWS McCarran Airport (MA)	664.780	3994.171	✔	
NWS Nellis AFB (NL)	677.049	4011.058	✔	

Topographic data required by the Diagnostic Wind Model were obtained from Clark County. Gridded terrain heights at 30 m were extracted from a Geographical Information System (GIS) database and aggregated to a 1 km grid covering the wind model domain (domain extent is discussed below).

LVV emissions data were obtained primarily from three County agencies; the Regional Transportation Commission (RTC) of Clark County, the Clark County Department of Comprehensive Planning, and the APCD. The variety of data and their specific sources are discussed below (see Table 10).

Review of Previous UAM CO Application for December 7-8, 1990

A detailed review of previous UAM CO modeling of the December 7-8, 1990 LVV episode was made in preparation of the Phase I modeling protocol for the current project. Many of the procedures developed for the 1990 modeling exercise were used in Phase I, and are expected to be used in Phase II. The protocol notes those areas in which our methodology departs from previous modeling. Part of the review of the 1990 application included a evaluation of DWM and UAM inputs. Overall, these inputs reflected the methodology reported, and appear to be adequate and follow EPA guidance for CO modeling.

We were able to identify some notable problems, however. First, it appears that the gridded terrain elevation data supplied to the DWM was reversed in row, meaning that the terrain field was in fact a mirror image of the actual terrain in the north-south direction. This places the Las Vegas Wash toward the eastern side of the LVV, but orients the outflow direction of the wash towards the northeast, rather than the southeast. More importantly in terms of terrain-induced flow patterns, mountain-valley configurations along the northern edge of the DWM were placed on the southern edge, and vice versa. It is difficult to say just how this affected wind patterns near the UAM-predicted CO maxima, as winds in central Las Vegas were dominated by the few wind observations in the area. That is, gridded winds would probably not have changed significantly near central Las Vegas if the terrain were corrected.

Second, the diffusion break was set at a constant value of 80 m for the duration of the run. No attempt was made to use the Desert Rock sounding on the afternoon of December 7 to characterize the mixing depths early in the simulation. Granted, insufficient vertical temperature soundings would have required subjectively specifying the diffusion break height, but a linear interpolation in time to the morning sounding (using the minimum of 80 m at that point) could have been made.

Third, temperature gradients above and below the diffusion break height were reported to have been calculated using the Desert Rock sounding and hourly NWS surface temperature observations made at McCarran Airport. The Desert Rock site is situated about 100 km to the northwest of Las Vegas and about 500 m higher in elevation. Combining data from such distant sites is inappropriate because both are highly influenced by local forcings. The stable

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nighttime temperature gradients below the diffusion break height were set to +10 to +60 K/km, which agrees with estimates from 1994 LVV tethersonde data with peaks around +45 K/km. However, the afternoon and late morning temperature gradients below the diffusion break were set to as low as -40 K/km. Lapse rates in well-mixed conditions (known as adiabatic) are around -10 K/km, and unstable (superadiabatic) lapse rates can reach values like -40 K/km in very shallow layers of about 10 m. Considering that the mixing depth is likely higher than 80 m during these periods, a value much more negative than the adiabatic lapse rate is incorrect. This likely led to much more vigorous mixing during the preceding afternoon and the following late morning.

Fourth, it was found that a parameter governing the relative weighting of terrain-induced "first-guess" wind fields and observations was set at 2 km. Since the DWM was run with 2 km grid spacing, this indicates that only those few cells containing observations were weighted towards observed winds, and that all other cells were weighted towards the diagnostic (terrain-modified) "first guess" fields. This is seen to limit the very low wind speeds observed at monitoring sites such as East Charleston to a single cell, and could potentially underestimate the extent of stagnation in the wash area.

DEVELOPMENT OF PHASE I BASE CASE INPUT FILES

Modeling Grid

The UAM and DWM grid structures were based on the grids used in previous UAM modeling of the LVV for the December 7-8, 1990 episode. Review of these grid structures, however, raised the question as to whether the horizontal coverage of the original UAM domain continues to encompass the City of Las Vegas, considering its rapid growth over the past six years and anticipated growth beyond the year 2000. In developing traffic data for mobile emission estimates, RTC staff analyzed current Traffic Analysis Zone and land use databases, and translated the extent of their spatial coverage to an "urban growth boundary". Assuming that the bulk of future urban growth will be contained within this boundary, it became evident that much of Las Vegas' growth will extend beyond the original UAM domain, particularly to the west and south. Discussions with the Project Oversight Committee yielded a consensus that the UAM domain should be expanded from a 40 by 40 grid to a 50 by 50 grid to entirely encompass the urban growth boundary. The only urbanized region that is not included in the grid is Boulder City, but this area is located outside the CO nonattainment basin. Emissions from that area should not have a significant impact on modeling results as drainage flow during CO episodes typically moves from the west/northwest to the southeast. Figure 1 displays the relationship between the CO nonattainment boundary and the original and current UAM modeling grids.

The UAM grid specifications for this study are as follows:

Origin in UTM zone 11:	642.000 km easting
	3973.000 km northing
Number of columns:	50 (E-W) by 50 (N-S)
Number of layers:	5 (4 below diffusion break and 1 above)
Cell size:	1 km
Minimum layer thickness:	20 m
Horizontal coverage:	2500 km^2
Vertical extent:	200 m

The use of four layers below the diffusion break height (depth of the inversion layer) in the 1990 UAM application was based upon evidence that the vertical CO concentration profile decreases rapidly within the surface-based inversion layer, and that at a minimum, four layers are needed to characterize this gradient (BRW and SAI, 1992). It was not made clear what information was used as evidence for this. While this appears to be quite adequate, experiments with an increased number of layers were undertaken to investigate UAM sensitivity to this approximation.

In simulating wintertime CO conditions, stagnant conditions allow for drainage flows to dominate the near-surface wind fields. In the LVV, surrounding terrain features may influence the drainage flow that sets up along the axis of the various washes. Thus, wind modeling for the 1990 UAM applications was performed on a grid that extends 20 km beyond the UAM grid in each direction to capture the potential influences of the significant terrain bordering the LVV. The DWM was designed to estimate mesoscale flow patterns and may generate unrealistically large slope-flows for high slope angles, which are likely to occur when terrain features are resolved at very small grid spacing. Acknowledging this drawback, the grid spacing in the 1990 DWM application was set to 2 km rather than the km specified for the smaller UAM grid.

The vertical extent of the 1990 DWM application was set to 200 m, divided into five layers each 40 m deep. It is difficult to ascertain the reasoning for using 40 m DWM layers when minimum UAM layer thickness of 20 m was set for the duration of the UAM simulation. With a 40 m layer structure, the first four UAM layers mapped to only two DWM layers, so vertical wind profiles were not accurately depicted in UAM. The lack of vertical wind soundings exacerbated this problem.

The DWM applications for the current study utilized a similar meteorological grid coverage as the previous study. However, use of tethersonde soundings allowed for a finer DWM layer structure, so the vertical resolution was doubled to 20 m to more closely match the nighttime UAM layer structure. Early Phase I DWM sensitivity testing revealed some important conclusions regarding horizontal resolution. First, given our knowledge of the DWM formulation, it was not obvious that the terrain features as much as 20 km beyond the border of the original UAM grid had any impact on LVV wind flow patterns. Only terrain features directly on and just inside the UAM border had some influence. Second, the use of 2 km grid

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spacing in DWM led to an overly smooth wind field, which would have required horizontal interpolation to the UAM grid. In areas with many monitors, this did not properly depict the light and variable nature of winds in the wash area, which in turn may not have led to a proper buildup and maintenance of high CO there. Third, the magnitude of the slope flow was not significantly affected by the use of a 1 km grid size, indicating that slope angles did not differ much from those at 2 km. The Phase I DWM horizontal grid resolution was therefore selected to be 1 km.

Figure 2 displays the horizontal coverage of the UAM and DWM grids in the LVV, with terrain contours and major traffic arteries overlaid. Figure 3 shows the UAM grid alone, indicating terrain contours, some major traffic routes, airports, and locations of APCD monitoring sites.

Episode Selection

All available meteorological and CO air quality data from the winter 1995/96 CO season were compiled and evaluated for Phase I modeling. The synoptic (or large-scale) meteorological regime associated with high CO episodes in the Las Vegas Valley was identified, and a conceptual model relating this regime to urban-level drainage flow in the Las Vegas Valley (LVV) was developed. Candidate CO episodes were compiled and analyzed for peak 1-hour and peak 8-hour CO concentrations at each monitoring station; winds and temperatures were also analyzed at each site for the period of 8-hour maximum CO. This was done to identify the degree of valley-wide cooling conducive to high CO emissions and a strong vertical stabilization, and the degree of valley-wide stagnation allowing CO buildup in the basin.

Our episode selection recommendation process was based upon the quality and quantity of available data upon which a reliable conceptual model may be based; the degree to which observed meteorological patterns for a given CO episode match historical patterns associated with the stagnation regime, and expected difficulty in UAM modeling such that a process-oriented model evaluation will be credible. Following EPA guidance procedures, the following conditions were met: (1) the episode did not appear to be the result of an exceptional event; (2) a complete routine data set was available; (3) the diurnal trends showed typical mid- to late-evening hour peak CO concentrations; and (4) the peak 8-hour concentrations indicated that high CO levels occurred at a several monitoring sites.

The 8-hour National Ambient Air Quality Standard (NAAQS) for CO (9 ppm) was exceeded on four occasions during the 1995/96 winter CO season. All exceedances were recorded at the East Charleston monitoring site, and at two nearly co-located supplemental sites called Proximity and Microscale (these two sites are within 50 m of the East Charleston probe). These exceedances were measured during the following evenings:

Date	Days	Peak 8-hour CO (ppm)
November 22-23, 1995	(Wednesday - Thursday)	10.2

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January 5-6, 1996	(Friday - Saturday)	10.1
January 13-14, 1996	(Saturday - Sunday)	10.3
March 9-10, 1996	(Saturday - Sunday)	10.1

Several characteristics were common to all four episodes. First, all peak 8-hour CO concentrations exhibited almost identical values. Second, peak 1-hour concentrations among these four episodes ranged from 11.2 ppm to 12.3 ppm, indicating that these episodes were not characterized by an isolated sharp 1-hour peak that led to high 8-hour averages. Rather, CO concentrations tended to build at East Charleston during the evening to a plateau of 9-12 ppm, where they remained for several hours. It was not clear that the traffic volume at the nearby "Five Points" intersection remained high throughout the night, which would be necessary to maintain a high CO level for many hours. Instead, this pattern suggested that the East Charleston site measured a pooling of urban-wide CO in this vicinity, which might have been emitted several hours before from a much larger area. Third, in contrast to other urban areas classified as CO nonattainment areas, all episodes during this season occurred on holidays or weekends (November 23 was Thanksgiving). Fourth, there was usually only one period of elevated CO concentrations, usually between 2200 and 0300 LST, which contrasts with other urban areas in that two peaks are measured, one in the evening and one in the morning, associated with weekday commute periods. While the CO exceedance patterns did not necessarily agree with the typical profiles discussed in the EPA CO guidance document, the consistency of the patterns episode to episode illustrated that the circumstances in Las Vegas are unique among CO nonattainment areas. This consistency also maximized our flexibility to choose any one of these episodes for Phase I modeling, as each was representative of a single conceptual model.

Remarkable consistency was also found in the larger synoptic-scale meteorological conditions from episode to episode. In each, the area of southern Nevada was dominated by the establishment and amplification of a surface high pressure system centered over the Great Basin (Nevada-Utah-western Colorado) after frontal passage 24-48 hours previous. Aloft, a very strong ridge was positioned along the Pacific Coastline, and a trough was centered over the central U.S. This widespread ridging in the west broadened the extent of the high pressure system at the surface, weakened pressure gradients that control the strengths of surface winds, increased static stability through the lower troposphere, and created conditions ideal for local stagnation and high stability in well-defined basins.

Once the large-scale forcing on near-surface atmospheric flow is reduced, the flow fields in the LVV become dominated by shallow local terrain-induced density currents that flow down mountain slopes and pool cool air into the lowest valley elevations. In the LVV, the lowest elevations are in the Las Vegas Wash in the eastern portion of the valley, which drains southeastward toward the Colorado River. Pooling of cool air further stabilizes the first 100-200 m above the ground, which in turn effectively terminates any vertical mixing in that layer. Analyses of observed wind patterns show continuous convergence of near-surface air from outer high elevation areas surrounding Las Vegas to the East Charleston area, which is located down in the wash. This conceptual model then explains that urban-wide CO emissions are being carried by the stagnation-induced density currents toward the Las Vegas Wash area, where they pool overnight and lead to elevated CO concentrations for many hours. Local “hot-spot” emission sources are seen to potentially exacerbate this problem.

Results of a more detailed analysis of CO and meteorological measurements made at APCD monitoring sites for each of the four episodes listed above are shown in Tables 2-5. Each table displays for each site the peak 1-hour CO, the peak 8-hour CO, and the 8-hour average wind speeds and temperatures for the period of peak 8-hour CO. The average values among all sites is also given at the bottom of the tables. The data in the shaded portions of the tables are not included in the average because: (1) the PM and BS sites (Paul Meyer and Craig Road/Bemis) affect the average with missing data; and (2) the MS and PX sites (Microscale and Proximity) bias the averages by triple-counting conditions in the East Charleston area.

As all episodes seemed to uniformly represent the typical conditions associated with CO events in the LVV, the analysis to choose one for modeling basically reduced to identifying that episode with the coolest temperatures (affecting CO emissions and stabilization), the most stagnation (affecting ventilation out of the wash) , the highest overall CO, and the most appropriate episode from a regulatory perspective. The November episode was characterized by the highest overall CO levels on average, followed by the January 5-6, January 13-14, and March 9-10. We disregarded the March episode because (1) it occurred very late in the season, which could be construed as an anomalous situation; (2) it was characterized by the lowest mean CO levels; and (3) the large-scale meteorological pattern departed the most from the conceptual model.

Average wind speeds among the remaining three events were all identical, again suggesting a remarkable degree of consistency in the weak flow patterns generated during stagnation in the LVV. While the November episode had the highest CO overall, the temperatures were much higher than the January periods (56 F versus 42 and 46 F). Further, the November episode was the only one to occur during the calendar year of 1995, which did not count toward a CO violation for 1995. In 1996, the first highest 8-hour CO exceedance was dropped (10.3 on the night of January 13-14), and the second highest 8-hour CO exceedance was specified as the nonattainment area’s design value (10.1 on the night of January 5-6, and March 9-10).

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Table 2. CO and Meteorological Conditions, November 22-23, 1995 (Wed-Thu)

Site	1-hour Max (ppm)	8-hour Max (ppm)	8-hour WS (MPH)	8-hour T (F)	Hours
EC	12.3	10.2	1.0	54	18-02
MC	10.5	8.4	1.6	59	18-02
CC	9.4	6.4	2.4	NA	16-24
SL	7.4	5.0	1.8	58	16-24
FL	6.8	3.9	3.3	57	17-01
WW	6.1	4.2	2.0	51	18-02
PT	3.6	1.9	2.5	55	17-01
PL	1.5	1.3	3.5	58	17-01
PM	1.2	NA	NA	NA	NA
BS	0.7	NA	NA	NA	NA
MS	NA	NA	NA	NA	NA
PX	NA	NA	NA	NA	NA
Average	7.2	5.2	2.3	56	

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Table 3. CO and Meteorological Conditions, January 5-6, 1996 (Fri-Sat)

Site	1-hour Max (ppm)	8-hour Max (ppm)	8-hour WS (MPH)	8-hour T (F)	Hours
EC	11.8	10.1	1.0	43	18-02
CC	9.5	6.6	2.4	NA	17-01
MC	7.3	5.9	2.0	43	18-02
SL	6.3	4.7	1.8	44	17-01
FL	5.6	4.4	3.0	44	18-02
WW	4.5	2.8	2.6	40	18-02
PT	3.6	2.8	2.3	41	18-02
PL	2.1	1.6	2.9	42	17-01
PM	2.6	1.3	4.0	50	13-21
BS	1.3	0.6	3.6	NA	16-24
MS	11.9	10.4	NA	NA	18-02
PX	11.1	9.5	1.6	44	18-02
Average	6.3	4.9	2.3	42	

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Table 4. CO and Meteorological Conditions, January 13-14, 1996 (Sat-Sun)

Site	1-hour Max (ppm)	8-hour Max (ppm)	8-hour WS (MPH)	8-hour T (F)	Hours
EC	12.1	10.3	1.0	46	18-02
CC	10.4	6.8	2.6	NA	17-01
MC	6.3	5.2	1.8	42	20-04
FL	5.4	4.7	3.2	50	17-01
SL	4.8	3.6	2.0	49	17-01
WW	4.1	3.1	2.2	43	18-02
PT	2.9	1.6	2.5	44	18-02
PL	1.5	1.0	3.3	48	16-24
PM	2.0	1.1	3.6	61	09-17
BS	1.6	0.7	2.6	NA	11-19
MS	13.0	10.8	NA	NA	18-02
PX	11.8	9.6	1.6	47	18-02
Average	5.9	4.4	2.3	46	

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Table 5. CO and Meteorological Conditions, March 9-10, 1996 (Sat-Sun)

Site	1-hour Max (ppm)	8-hour Max (ppm)	8-hour WS (MPH)	8-hour T (F)	Hours
EC	11.2	10.1			18-02
MC	8.9	7.1			19-03
CC	7.4	6.1			18-02
WW	5.0	3.3			18-02
FL	4.7	3.5			18-02
SL	3.9	2.8			18-02
PT	1.7	1.1			19-03
PL	1.1	0.8			18-02
PM	1.0	0.5			11-19
BS	0.8	0.5			16-24
MS	NA	NA			NA
PX	NA	NA			NA
Average	5.5	4.4			

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The January 5-6, 1996 CO episode was selected for Phase I modeling for the following reasons:

- Of the episodes in 1996, it had the highest site-average 1-hour and 8-hour CO concentrations, indicating higher CO in the basin overall;
- The 8-hour CO exceedance was the current design value for the Las Vegas nonattainment area;
- It was the coolest of all episodes, with an average 8-hour temperature of 42 F.

DWM Modeling

The general approach in developing meteorological inputs for UAM is fully discussed in the Phase I Modeling Protocol, and in many ways incorporated the procedures and parameter settings used in modeling the December 7-8, 1990 episode. The Diagnostic Wind Model (DWM) was used to supply hourly three-dimensional wind fields to UAM. Sensitivity studies were employed to investigate potential improvements to the modeling methodology and to investigate model behavior to changes in parameters that are considered the most uncertain. A final set of DWM wind fields were developed using optimal selections for parameters identified in the sensitivity tests.

As discussed in the modeling protocol, the lack of routine upper-air meteorological data with adequate time and vertical resolution presented some problems associated with UAM modeling for the area. This major data gap is to be remedied during the Phase II intensive field study. Tethersonde profiles of temperature and winds recorded by DRI during a January 1994 tracer gas field experiment represented a very plausible source for vertical data, provided that the meteorological conditions were consistent among an episode in January 1994, and the Phase I January 5-6, 1996 modeling episode. Unfortunately, while a few periods of high hourly CO occurred during the field study, the 8-hour standard was not approached. It is quite possible then, that meteorological conditions were not so severe as to be fully representative of an exceedance event.

An analysis of all available field data taken during the marginal CO events of January 1994 was undertaken, in particular to compare wind and temperature data to conditions during the Phase I CO event. The remarkable consistency between the four 1995/96 episodes was found to extend to January 1994 as well, with the development of widespread high pressure over the Great Basin following frontal passage the previous day. On the local scale, 1994 wind data from a set of supplementary wind sites were compared to wind data from the Health District's monitoring network during the January 5-6, 1996 episode. As expected, results indicated that the valley-wide wind patterns set up during the 1994 elevated CO episodes were quite similar to those in the 1996 episodes. It was therefore decided that tethersonde data from January 14-15, 1994, be utilized in the development of both Phase I UAM and DWM input files.

Estimates of mixing depth, inversion depth, vertical temperature gradients, and domain mean wind were generated by analysis of routine NWS rawinsonde data from the Desert Rock site in conjunction with the tethersonde data. Soundings from Desert Rock were available at 12-hour intervals (1600 and 0400 LST each day) and typically provided 4-5 data levels below 1000 m. These data were used primarily to estimate afternoon mixing depths and lapse rates. The NWS soundings were also used to supply a more regional value of lower tropospheric mean flow and inversion strength for DWM, which is more appropriate for the mesoscale terrain flow estimates diagnosed by the wind model. The tethersonde data offered much better resolution in both time (typically at 30 minute intervals) and height (10-20 levels under 100 m), allowing very accurate diagnosis of UAM inversion depth and strength during the night in the Las Vegas Wash area. It was assumed that the values extracted from NWS and tethersonde data were spatially invariant and applied throughout the entire LVV.

The Phase I DWM run parameters are given in Table 6, while Table 7 presents the hourly domain mean wind and temperature lapse rates. The domain mean wind represents near-surface regional average flow that is locally adjusted for terrain effects such as slope heating/cooling, blocking, and kinematic accelerations. As such, the mean direction through the lowest 500 m was calculated from the Desert Rock sounding at 1600 LST January 5, and at 0400 LST January 6, and linearly interpolated for hours between these times. Average wind speeds in this layer were measured to be light, and so mean wind speed was held constant at the average of 5 knots (2.5 m/s) for all hours. Wind speed and direction before 1600 and after 0400 were held constant. Similarly to the domain mean wind, temperature lapse rates should represent the regional lower atmospheric lapse rate that controls the kinematic effects, the strength of slope flows, and the influence of terrain blocking. The average lapse rate below 500 m was calculation from the two Desert Rock sounding times and realistically (rather than linearly) varied to each intermediate hour. It was assumed that the lapse rate at 0400 would remain constant to sunrise at about 0700; the rate at which temperature gradients decrease after 0700 are arbitrary but appropriate.

The selection of the parameters in Tables 6 and 7 resulted in the best agreement between observations and our conceptual model of LVV flow during stagnation events. Also, the magnitude and direction of the diagnosed down slope flow field in the westernmost portion of the valley agreed quite well with the wind observations in that area. An typical example of the surface and 90 m wind fields for the January 5-6 episode (2100 or 9 PM LST) are given in Figure 4.

A sensitivity test was performed in which the DWM was supplied with the extreme vertical temperature gradients measured by the tethersonde below 100 m. This resulted in very large and unrealistic downslope velocities, and supported our understanding that DWM requires a more regional (and vertically deeper) average lapse rate, rather than a highly localized value.

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Table 6. DWM input parameters.

Parameter	Value	Comments/description
ZSWIND	10	Height of surface wind measurements (m)
RMIN	1.	Minimum interpolation distance (km)
RMAX1	10.	Maximum radius to search for surface wind observations over land (km)
RMAX2	30.	Maximum radius to search for upper air wind observations over land (km)
R1	5.	Distance at which surface wind observations and diagnostic wind field are equally weighted (km)
R2	20.	Distance at which upper air wind observations and diagnostic wind field are equally weighted (km)
NINTERP	2	Maximum number of nearest surface wind observation sites to include in distance-weighted averaging with diagnostic wind field
NITER	50	Maximum number of iterations to take in divergence minimization step
DIVLIM	1×10^{-5}	Maximum allowable divergence (s^{-1})
IOBR	0	Use the O'Brien adjustment scheme (0=no)
NSMTH	2	Number of passes in smoothing step
IEXTRP	1	Extrapolate surface observations aloft (1=no)
CRITFN	1	Critical Froude number
TERRAD	10	Maximum distance at which terrain features cause blocking effects (km)
IFRADJ	1	Calculate Froude adjustment effects (1=yes)
IKINE	1	Calculate Kinematic effects (1=yes)
ALPHA	0.1	Parameter controlling influence of kinematic effects

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Table 7. Hourly domain mean wind direction and temperature lapse rates supplied to the DWM. A constant mean wind speed of 2.5 m/s was assumed.

Hour	Domain Mean Wind Speed (m/s), Direction (deg)	Domain Mean Temperature Lapse Rate (K/km)
1500	225	-11.8
1600	225	-12.2
1700	240	-1.2
1800	255	0.1
1900	270	1.1
2000	285	2.0
2100	300	2.8
2200	315	3.5
2300	330	4.1
0000	345	4.6
0100	0	5.0
0200	15	5.3
0300	30	5.5
0400	45	5.6
0500	45	5.6
0600	45	5.6
0700	45	5.6
0800	45	2.2
0900	45	-1.0
1000	45	-3.8

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A sensitivity test was also performed in which the 100 m mean wind speed and direction from the tethersonde soundings were used to specify the hourly domain mean wind (an example of the resulting wind fields are shown in Figure 5 for the same hour as in Figure 4). This resulted in much lighter wind speeds overall (often less than 1 m/s) but a more consistent northwesterly direction hour to hour. While agreement between surface observations and surface flow patterns away from measurement sites deteriorated, better agreement was obviously found aloft between the domain mean wind and the single tethersonde sounding. The winds measured by the tethersonde were construed to be only representative of the area around East Charleston, and not adequate to represent the entire basin in terms of a domain mean wind. Nevertheless, this sensitivity wind field was reserved for a UAM sensitivity simulation to investigate air quality sensitivity to wind field inputs.

UAM Input File Preparation

Emissions, meteorological, and air quality files were developed in UAM format for the Phase I episode. Meteorological files include UAM-formatted 3-D wind fields, 2-D surface temperature fields, 2-D diffusion break fields, and stability measures (e.g., vertical temperature lapse rates and exposure class). Air quality files include UAM-formatted 3-D initial conditions, 2-D boundary concentrations, and 2-D top concentrations. All data files were developed using data available from all available monitoring sites operating during the episode, as well as the January 1994 special study tethersonde data. All UAM input files underwent quality assurance examinations before running UAM for the base case, as described in the Phase I modeling protocol.

A SIMCONTROL file was generated for each individual run of UAM. The UAM was started at 1500 LST on January 5, and allowed to run through 1100 LST the following day. Sensitivity tests performed early in Phase I, as well as those performed during the 1990 UAM application, revealed that the impacts of initial conditions on peak 8-hour CO concentrations were minimal to non-existent. The CHEMPARAM file was set up to designate the simulation of a single unreactive non-depositing CO species. The REGIONTOP file specified a time- and space-invariant model top at 200 m. The contents of the TERRAIN file are immaterial when modeling inert non-depositing species, but the file is required by the model. Space-invariant defaults were supplied.

The WIND file was generated from the DWM hourly fields using the UAMWND preprocessor. This processor contains an O'Brien adjustment wherein vertical velocities are set to zero at the top of the modeling grid, and horizontal winds are readjusted through a divergence minimization procedure. This process can lead to drastic and unreasonable effects on horizontal winds, and has often been called into question for ozone applications in which the top of the grid is as high as 3-4 km. Use of a 200 m model top in this CO exercise greatly exacerbates these effects, and so UAMWND was modified to skip the O'Brien procedure.

The UAM has been shown to be quite sensitive to the selection of the DIFFBREAK height,

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particularly in modeling CO episodes. Correct specification of the depth of the nocturnal inversion layer is crucial to proper simulation of the evolution of the pollutant field, and UAM simulations benefit greatly from high resolution sounding data. Hence, tethersonde data from the January 14-15, 1994 CO episode were used to set hourly DIFFBREAK values. Since most tethersonde ascents were made just about half-hourly, it was necessary to determine hourly averaged soundings. Hour averages were constructed by averaging the two soundings at the top of consecutive hours with the one intervening. The depth of the nocturnal sounding was taken as the height at which a discernable change in temperature lapse rate occurred. Afternoon and late morning values for DIFFBREAK were set to 200 m as the tethersonde data indicated a mixed layer depth beyond the depth of the 100-150 m sounding. The resulting hourly DIFFBREAK values are shown in Table 8.

The most important parameters carried by the METSCALARS file are the temperature gradients above and below the DIFFBREAK height. These, in concert with exposure class, control the rate of mixing across layers, which becomes crucial during local nighttime stagnation. Similar to the problems associated with specifying DIFFBREAK, a highly resolved vertical sounding data set is required to accurately specify temperature gradients. In Phase I modeling, these gradients were easily obtained from the tethersonde data of January 14-15, 1994. Since the sounding measurements ended at 0700, it was assumed that the lowest 200 m would reach adiabatic (neutrally mixed) lapse rates (-10 K/km) by 0900.

Exposure class was estimated based on hourly calculated solar elevation angles and by assuming a clear sky. Exposure values of -2 represent zero solar energy and clear skies (heat loss via a radiation deficit), while values of 1 represent solar energy at low elevation angles (morning and evening) and clear skies (small heat gain via radiation surplus). Atmospheric pressure, water vapor, and NO_2 photolysis rate constants are not required in inert CO modeling, and so were assigned default values. Hourly exposure class and temperature gradients are also indicated in Table 8.

The TEMPERATURE file is primarily used for reactive UAM applications, but it also slightly affects CO concentrations by modifying atmospheric density. A TEMPERATURE file was generated using the standard UAM preprocessors and hourly data from East Charleston.

The lateral boundary concentration field was developed using recommended background levels from the CO guidance document (0.2 ppm). There are no CO monitors within 10 kilometers of the boundary. While it is noted that the UAM boundaries are located in very rural desert terrain that could reflect clean tropospheric values (0.1 ppm), a higher value will likely reflect the basin-wide buildup of CO in the LVV overnight. Further, clean tropospheric background CO levels have been seen to increase to about 0.2 ppm. Concentrations above the model top were also set to the clean tropospheric background value of 0.2 ppm.

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Table 8. Hourly diffusion break, temperature gradient (above and below the diffusion break), and exposure class supplied to the UAM base case simulation.

Hour	DIFFBREAK (m)	Temperature Gradient (K/km)		Exposure Class
		Below	Above	
1500-1600	200	-12	-5	1
1600-1700	200	11	-5	1
1700-1800	40	11	-5	-2
1800-1900	60	19	-5	-2
1900-2000	80	24	-5	-2
2000-2100	82	24	-5	-2
2100-2200	83	32	-4	-2
2200-2300	85	45	-4	-2
2300-2400	87	47	-4	-2
0000-0100	88	44	-4	-2
0100-0200	90	48	-4	-2
0200-0300	100	38	-4	-2
0300-0400	107	42	-4	-2
0400-0500	113	28	-4	-2
0500-0600	120	27	-4	-2
0600-0700	128	34	-4	-2
0700-0800	137	10	-4	-2
0800-0900	145	0	-4	1
0900-1000	170	-10	-4	1
1000-1100	200	-10	-4	1

The initial concentration field was developed from all available CO measurements within the UAM domain at 1500 LST January 5. These were interpolated to the modeling grid using the standard UAM AIRQUALITY preprocessor. Values near the boundaries were set to low background values of 0.2 ppm through the use of several pseudo-stations; concentrations were linearly scaled from the surface to the model top value of 0.2 ppm. An isopleth plot of initial concentrations in UAM layer 1 is shown in Figure 6.

Emissions Modeling

The January 5-6, 1996 base case episodic emissions inventory was developed from 1995 emissions data following EPA emission inventory preparatory guidelines described in the Modeling Protocol. These guidelines cover the estimation and projection of emission inventories as well as the procedures for developing UAM emissions files for episodic applications. Details of the episodic emissions inventory development for Phase I are presented below, including data sources, summary of emission totals by source category, spatial distributions, and descriptions of any deviations from the Modeling Protocol, if applicable.

Overall, the total anthropogenic CO emissions inventory is dominated by on-road mobile sources. Table 9 presents the 1995 base year and the UAM episodic emissions inventory by source category. For both the base year and the 18-hour UAM episode, the on-road mobile source portion of the inventory is approximately 90 percent. The spatial distribution of the total anthropogenic inventory for the UAM episode is presented in Figure 7. Because of the dominance of on-road mobile sources, the distribution of the total inventory shown in Figure 7 follows along the major roadways in the Las Vegas Valley.

<u>On-road Mobile Sources</u>

The on-road mobile source inventory was calculated using link and activity data from TRANPLAN, emission factors from MOBILE5a, and processing using DTIM2. The sources of mobile source modeling data are included in Table 10. The 1995 base year inventory for on-road mobile sources was estimated from 1995 annual VMT and fuel parameter data, and hourly temperature from East Charleston on January 5-6, 1996. In general, the emission inventory development followed the Modeling Protocol with the exception of the development of the diurnal activity profile.

The Regional Transportation Commission (RTC) supplied diurnal activity data for three cases: weekday, Saturday and Sunday. It was noticed that for Friday (January 5) the weekday diurnal data did not appear to adequately model the late evening activity that is assumed to be similar to Saturday evening activity. Thus, a Friday-specific diurnal profile was created by combining the 1 AM - 6 PM weekday profile with the 7 PM - midnight Saturday profile. The net effect was a small increase in the activity distribution after 7 PM Friday night. A comparison of the standard diurnal profile data from RTC and the modified distribution developed for this study

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is shown in Figure 8. Notably, the modified distribution appears to more accurately model the transition from Friday to Saturday, confirming the reasonableness of this approach.

Overall, the on-road mobile sources are the largest contributor to CO emissions in the 1995 base year and UAM episode emission inventories (Table 9), accounting for nearly 90 percent of all CO in the Valley. The spatial distribution of the mobile source emissions is presented in Figure 9.

Point Sources

All sources whose location was fixed in the modeling domain were modeled as point sources. This included the standard stationary point sources as well as the emissions from the airports and locomotives. The sources of point source emissions data are included in Table 10. In modeling aircraft and locomotives, the sources were assumed to have no "stacks" and therefore emitted CO at the ground level. Emissions for aircraft were assigned to the appropriate grid cells for each airport and locomotive emissions were assigned to the grid cells containing the rail yards. For stationary point sources, the emissions were estimated in accordance with the Modeling Protocol. For those stationary sources for which stack parameter or operation data were not provided, EPS modeling defaults were used.

Overall, point sources make up about 6 or 7 percent of both the 1995 base year and UAM episode inventories (Table 9). These emissions are primarily from aircraft operations. The spatial distribution of point source emissions is presented in Figure 10. As expected the largest sources occur at the location of the airports.

Area Sources

Area source emissions represent the aggregate of several minor categories whose emissions are assigned according to land use distribution data. In general, the area source emissions were modeling in accordance with the Modeling Protocol. The sources of area emission data are included in Table 10. Note that the 1995 base year data are those from the 1992 BRW/SAI Study, and included in these data are several small stationary sources now included in the point source inventory data described above. To avoid potential double counting, the small stationary sources now included in the point source data were summed and subtracted from the BRW/SAI area source data. These source accounted for 572 tons/year in the 1995 base year inventory.

Overall, area sources make up about 3 or 4 percent of both the 1995 base year and UAM episode inventories (Table 9). The primary source of area source emissions is construction equipment. The spatial distribution of area source emissions is shown in Figure 11.

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Table 9. 1995 base year CO emissions and UAM 18-hour episode CO emissions for the Las Vegas Valley.

Source Category	Subcategory	1995 Base Year Emissions		UAM Episode Emissions	
		Tons/Year	% of Total	Tons	% of Total
Point	Stationary sources	2,231			
	Nellis AFB (aircraft)	1,045			
	McCarran Airport	4,960			
	North Las Vegas Airport	973			
	Henderson Airport	252			
	Locomotive	84			
	Total	**9,545**	**6.9%**	**19.8**	**6.3%**
Area	Small stationary	411			
	Boiler emissions	104			
	Fireplaces/woodstoves	774			
	Structural fires	235			
	Vehicular fires	20			
	Brush fires	460			
	Residential nat. gas com.	112			
	Commercial nat. gas com.	33			
	Industrial nat. gas com.	117			
	Utility nat. gas com.	203			
	Cigarette smoking	16			
	Lawn & garden equip.	156			
	Construction equipment	3,566			
	Total	**6,207**	**4.5%**	**10.6**	**3.4%**
Mobile	**Total on-road vehicles**	**121,826**	**88.6%**	**282.8**	**90.3%**
Total		**137,578**	**100.0%**	**313.1**	**29.5279135**

Table 10. Emission inventory data sources.

Source Category	Source	Data
Point	Dept. of Comprehensive Planning	Stationary point source emissions and non-aircraft emissions for Nellis AFB taken from the 1995 permit data.
	Dept. of Aviation	Emission inventory for McCarran Airport.
	1992 BRW/SAI Study	1995 emissions for North Las Vegas and Henderson Airports, Nellis AFB (aircraft) and locomotives; stack parameters for major stationary point sources.
Area	Regional Transportation Commission	1995 land use distribution data.
	1992 BRW/SAI Study	1995 area source emission inventory.
On-road Mobile	Regional Transportation Commission	1995 TRANPLAN activity data and link network; diurnal, day-of-week and monthly activity data.
	1992 BRW/SAI Study	Cold and hot start diurnal profiles.
	Dept. of Comprehensive Planning	MOBILE5a input file data.

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UAM RESULTS

The UAM was run for a base case simulation of the January 5-6, 1996 LVV CO episode, using the input fields generated as described above. Results from this simulation and several sensitivity tests are described below; predicted concentration fields were analyzed to assist in the placement of supplemental portable CO monitors and meteorological sites for the Phase II 1996/97 field monitoring exercise. General findings of these UAM applications are summarized in the Conclusion section at the end of this technical memorandum.

Base Case

A plot of the spatial distribution of peak hourly CO concentrations predicted by the UAM Base Case is shown in Figure 12. Note that the peak CO in each cell is identified and plotted, and that the hours at which each maximum occurs likely differ cell to cell. The peak hourly measured CO at APCD sites are overlaid onto the contours of predicted CO. Overall, the UAM predicts a similar pattern to that measured, including the peak CO in the East Charleston area, elevated CO near the center of Las Vegas and along the southeastern extent of highway 95, and markedly lower CO levels in outlying areas. However, the UAM under predicts most CO measurements. Consistent but under predicted CO patterns are also noted for the plot of gridded peak predicted 8-hour average concentrations with corresponding measurements (Figure 13).

Figure 14 displays time series plots of UAM predictions and APCD observations. The solid line represents the predicted CO at the location of the measurement site, while the measurements are indicated by dots. The dashed lines show the range of UAM predicted concentrations in a 9-cell area surrounding the measurement site location. This is useful to indicate if a site is located in an area of large predicted CO gradient, and to suggest the degree of model uncertainty in CO cloud placement. It is obvious from this figure that for sites with elevated CO, UAM is tracking the time evolution of CO fairly well, but consistently under predicts. The range of CO predicted in nearby cells is often sufficient to bring UAM into closer agreement with observations, except in the morning hours (5-9 AM).

A statistical model performance evaluation was performed in which EPA-guidance statistics were calculated for predicted vs. observed peak concentrations (i.e., paired in space, but not in time), and for predicted vs. observed concentrations for all hours (i.e., paired in space and time). Guidance suggests that performance statistics be based on prediction-observation pairings above 5 ppm. However, the highly localized nature of the observed CO cloud (only a few sites for a few hours above 5 ppm) combined with the UAM under predictions, leads to very few pairings, and hence a statistically insignificant evaluation. A lower cutoff of 1 ppm was used instead.

Statistical results for hourly concentrations are given in Table 11. The UAM does not capture

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Table 11. Hourly model performance statistics for the Las Vegas CO Base Case.

Peak Prediction Statistics for CO

Peak Observed ppm:	East Charleston	9600523 - 9600524	11.8
Peak Predicted ppm:	Cell (27, 31)	9600521 - 9600522	10.6
Unpaired Peak Prediction Accuracy (%):			-9.8

Peak Predicted/Observed by Site:

Site	Predicted ppm	Predicted hr	Observed ppm	Observed hr	Error ppm	Error %	Time Diff hours
East Charleston	8.2	23	11.8	23	-3.5	-30.0	0
City Center	6.0	19	9.5	20	-3.5	-36.9	-1
Maycliff	5.5	23	7.3	1	-1.8	-25.3	-2
Winterwood	3.7	19	4.5	19	-0.8	-17.3	0
Powerline	-999.0	-999	2.1	20	-999.0	-999.0	-999
Craig Road/Bemis	-999.0	-999	1.3	17	-999.0	-999.0	-999
East Flamingo	5.8	18	5.6	0	0.2	2.8	-6
Shado Lane	5.9	21	6.3	19	-0.4	-6.7	2
Paul Meyer	1.4	17	2.6	17	-1.2	-46.5	0
Pittman	2.2	19	3.6	18	-1.4	-37.8	1
Average:					-1.6	-24.7	-1

Number of Stations: 10
Number of valid peak pairs: 8

Overall Statistics for CO

For Concentrations above	(ppm):	1.0
Average UAM Prediction	(ppm):	1.7
Average Observation	(ppm):	2.9
Difference in Averages	(ppm):	-1.2
	(%):	-41.4
Bias	(ppm):	-1.5
	(%):	-41.6
Error	(ppm):	1.6
	(%):	44.7
RMS Error	(ppm):	2.1

Number of total pairs: 200
Number of valid pairs: 150
(%) 75.0

EPA Definitions:
Bias = Bias (ppm)
Normalized Bias = Bias (%)
Gross Error = Error (ppm)
Normalized Gross Error = Error (%)

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the peak observed CO at East Charleston, whether on a space-paired basis (30% under prediction at the measurement site), or on an unpaired basis (10% under prediction using peak anywhere in the grid). The average under prediction of all peak hourly CO is 25%, and the overall model bias indicates an under prediction of over 40%. These are at the upper limit or outside the EPA guidance for acceptable model performance. Note, however, that UAM does a good job at replicated when the peaks occur, where the average difference in time of modeled vs. observed peaks is only one hour. Peak and overall statistics calculated for 8-hour average concentrations (Table 12) indicate very similar performance, with a negative bias of around 40%.

Sensitivity Cases

UAM performance is promising in that the evolution of the Las Vegas CO cloud, subsequent transport, and intensification agree with our conceptual model based on observations, knowledge of emission patterns, and previous field work. However, the UAM base case underestimates measured nightly peak CO concentrations at most monitoring sites, especially at East Charleston, and completely misses several observed mid morning peaks. Further, overall statistics for hourly and 8-hourly concentrations are outside the range of acceptable performance as given by EPA guidance because of large underestimate bias.

Several sensitivity evaluations were carried out, with particular regard to those identified in our proposal and Phase I modeling protocol to address the most likely source of UAM error. Those previously identified included incorporating much higher vertical resolution with a static grid system, and use of 10-minute winds to improve the stochastic characterization of stagnation and meandering. Sensitivity to mobile emissions (shift in diurnal activity by 2-3 hours, inclusion of off-cycle contributions) were also carried out.

Fine Vertical Grid Structure

The diffusion break was originally designed for ozone applications in which pollutants are mixed through a deep afternoon mixed layer, but fresh emissions are trapped within a shallow nighttime stable layer and decoupled from older pollutants aloft. As described in the modeling protocol, the UAM's numerical process associated with the evening breakdown of a well mixed layer concurrent with the buildup of a surface-base nighttime stable layer is inconsistent with the actual processes. This transition between deep afternoon mixed layer to shallow evening stable layer is a complex process that cannot be described simply as a lowering of the diffusion break height. Further, a progressive deepening of the inversion layer at night leads to a deepening of each model layer below the diffusion break. This was seen in the base case to result in artificial dilution of pollutants in the surface layer during the early morning hours.

It is important to realize that for CO modeling, the vast majority (if not all) of emissions are trapped into the first model layer between the hours of 5 PM and about 8 AM the following day, simply because the large stable temperature gradients and nighttime exposure class severely limit mixing to higher layers. The thickness of the surface layer therefore becomes a crucial factor in

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Table 12. 8-hourly model performance statistics for the Las Vegas CO Base Case.

```
Peak Prediction Statistics for CO
--------------------------------------------------------------------------------
Peak Observed  ppm: East Charleston      9600518 - 96006 2      10.1
Peak Predicted ppm: Cell ( 28, 31)       9600518 - 96006 2       8.0
Unpaired Peak Prediction Accuracy (%):                         -20.9

Peak Predicted/Observed by Site:
                          Predicted       Observed         Error       Time Diff
       Site               ppm    hr      ppm    hr       ppm        %      hours
East Charleston             6.6   18      10.1   18      -3.5     -34.6         0
City Center                 3.3   17       6.6   17      -3.3     -49.9         0
Maycliff                    4.7   18       5.9   19      -1.2     -19.6        -1
Winterwood                  2.7   18       2.8   18      -0.1      -4.7         0
Powerline                -999.0 -999       1.6   17    -999.0    -999.0      -999
Craig Road/Bemis         -999.0 -999    -999.0 -999    -999.0    -999.0      -999
East Flamingo               3.2   17       4.4   18      -1.2     -27.4        -1
Shado Lane                  4.3   16       4.7   17      -0.4      -8.2        -1
Paul Meyer               -999.0 -999       1.2   15    -999.0    -999.0      -999
Pittman                     1.5   18       2.8   18      -1.3     -47.5         0
            Average:                                     -1.6     -27.4         0
Number of Stations:          10
Number of valid peak pairs:   7
--------------------------------------------------------------------------------

Overall Statistics for CO
--------------------------------------------------------------------------------
For Concentrations above (ppm):   1.0
Average UAM Prediction   (ppm):   1.9
Average Observation      (ppm):   3.2
Difference in Averages   (ppm):  -1.2
                           (%): -38.6
Bias                     (ppm):  -1.4
                           (%): -38.8
Error                    (ppm):   1.4
                           (%):  39.6
RMS Error                (ppm):   1.7
Number of total pairs: 130
Number of valid pairs: 103
                   (%)  79.2
--------------------------------------------------------------------------------

 EPA Definitions:
 Bias                   = Bias (ppm)
 Normalized Bias        = Bias (%)
 Gross Error            = Error (ppm)
 Normalized Gross Error = Error (%)
```


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resulting pollutant concentrations, and this is driven by the hourly specification of diffusion break height. The diffusion break has been found to be a very effective “tunable” parameter to adjust CO peaks to just about any value the modeler requires, particularly in cases in which no data are available in the vertical.

A sensitivity case was undertaken to examine UAM response to the removal of any artificial influence resulting from the diffusion break. The model was configured with a 10 layer fixed vertical grid, with each layer specified to be 20 m deep. Note that specification of 20 m layer thickness is arbitrary, but it was selected based on minimum surface layer thickness occurring in the base case. By specifying that all layers exist below the diffusion break, which was set to the region top height (a constant 200 m), this shallow model’s vertical structure was treated in a much more uniform manner. As usual, vertical diffusive transfer between layers was controlled by the input exposure class and temperature gradients below the diffusion break. This allowed for a more realistic shutdown of mixing across all vertical layers in the early evening and removed the artificial mass dilution of surface-layer pollutants during the night.

Figure 15 presents the gridded peak predicted hourly CO concentrations, with hourly measured maxima overlaid at the locations of monitoring sites. Comparison of this figure with Figure 12 (Base Case) shows that the absolute maximum predicted slightly increased (10.73 ppm vs. 10.62 ppm in the Base Case), but the overall pattern is quite similar. Notable exceptions include higher peak predicted CO near McCarran Airport, and a definite shift in the CO pattern extending southeastward to more along highway 95 into Henderson.

Time series plots of this test are shown in Figure 16 (dashed line), which includes the base case (solid line) and observations (dots) for comparison. Note that at all sites, the model indicates very little sensitivity to this rather drastic modification of vertical structure. The most notable effects are during the morning of January 6 (5 to 9 AM) when the UAM predicts slightly higher CO at many sites than in the Base Case. This is a result of removing the artificial dilution occurring from a deepening of the inversion depth during these hours. However, these improvements are insignificant, and result in only a minimal improvement to important performance statistics (Table 13; compare “Run 5" to “Base”).

Since the depth of the surface layer in the Base Case ranged from 20 m at 1700 (5 PM) to 35 m at 0800, the small differences in predicted CO patterns between the Base Case and this test show that most CO is carried in the surface layer. Overall, these results strengthen the argument that the depth of the surface layer controls predicted CO concentrations as most emissions are emitted into this layer at night and do not mix vertically. The UAM, regardless of the vertical structure specified, is therefore reduced to a single surface layer model as it implies a vertically uniform CO distribution through 20-40 m. Given the UAM numerics, specifying more layers within this depth to resolve a vertical distribution would only serve to trap all CO into an even thinner surface layer and drastically increase concentrations.

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Table 13. Comparison of selected statistics among all UAM simulations. All values in percent.

UAM Run	Unpaired Peak Prediction Accuracy	Peak Prediction Accuracy at EC	Average Peak Prediction Accuracy	Overall Bias	Overall Gross Error
Base Case	-10	-30	-25	-42	45
Run 5	-9	-28	-29	-37	42
Run 3	-10	-23	-22	-37	42
Run 4	-5	-29	-23	-32	38
Run 11	-12	-26	-15	-25	37
R6	0	-22	-20	-35	41
R1g	+23	-8	+1	-34	48
R5	+31	-23	+1	-25	48

10-Minute Wind Inputs

Most, if not all, operational air quality models operate on an hourly basis, i.e., input fields are read each hour and held constant for the duration, while the model integrates forward each time step (typically 5-20 minutes) and outputs hour average concentrations. For reasons discussed in the modeling protocol, use of hour-average wind fields (and to a lesser extent hourly stability and temperature) has many drawbacks when modeling CO stagnation events. The stochastic nature of the real wind fields is a dominant component during stagnation as the presence of weak turbulent eddies are not masked by strong mean flow forcings, but these effects are removed with the use of hourly averaged data. The net effect is to artificially move mass on the grid in a constant pattern for the duration of an entire hour.

The potential influence of this problem on UAM performance was evaluated by incorporating the stochastic component into the wind fields in a sensitivity test. Ten-minute wind data from APCD monitors were supplied to DWM to generate input wind fields at the finer time resolution, rather than hourly. In this way, the wind fields include the natural measured temporal variations associated with a much smaller time scale. UAM can treat gridded inputs at any time interval, so it was not necessary to modify the UAM code itself to handle such wind fields.

Figure 17 shows the gridded hourly maximum CO patterns predicted in the ten-minute wind test. Compared to the Base Case (Figure 12), differences in the maximum CO are minimal. However, note that the area within the 9 ppm curve in the area of East Charleston (denoted by the 12 ppm peak observation) is larger than in the Base Case, suggesting that the use of 10-minute winds in that area maintain and build up the CO cloud rather than transport it away.

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Time series plots comparing the Base Case with the ten-minute wind results (Figure 18) show that the latter improves the prediction at East Charleston during the peak period somewhat. This is also true at a few other sites (e.g., Maycliff and Shadow Lane). The ten-minute case also leads to some worse under predictions in early morning hours. Performance statistics for this test (denoted by the “Run 3" in Table 13) indicate only marginal improvement, similar to the 10-layer case (“Run 5"). Overall, results are inconclusive, but the signal found in peak performance at East Charleston and other sites, and to the size of the predicted 9 ppm CO cloud in that vicinity, are consistent with our ideas that hourly inputs are not adequate to properly characterize stagnation events.

Light Domain Mean Winds

A DWM sensitivity test was performed in which the 100 m mean wind speed and direction from the January 1994 tethersonde soundings were used to specify the hourly domain mean wind instead of mean 500 m winds from the Desert Rock sounding (as discussed above). Although the overly stagnant wind field was deemed to be inadequate as the optimal field for the base case UAM simulation, it was used in a UAM sensitivity test as another evaluation of model performance response to input winds. Figure 19 shows the gridded hourly maximum CO predicted in this low mean wind case. The overall peak was predicted to increase to 11.24 ppm (Base Case peak was 10.62 ppm), which is the largest increase produced by sensitivity tests discussed so far. The shift in southeastern extent of the 1 ppm contour is similar to the 10-layer case, and the increase in the size of the 9 ppm contour in the East Charleston area is slightly smaller than the ten-minute wind case. The largest differences would be expected to occur in areas of the grid removed from meteorological observation sites, where the gridded winds are dominated by the specification of the domain mean wind. This appears to be the case in the southeast and northeast. The gridded winds in the East Charleston area are dominated by the surface observations there and by the tethersonde data. Small increases in the size of the 9 ppm CO cloud in that region indicate that there is minimal sensitivity in that area.

Time series comparing the light mean wind case with the Base Case are shown in Figure 20. Again, very little sensitivity is shown by altering the domain mean wind, mainly because all sites presented in these plots have co-located meteorological measurements that dominate the local wind field in DWM. Small improvements seem to be balanced by small deterioration at all sites. Comparison of performance statistics in Table 13 indicate that indeed the low mean wind case (denoted as “Run 4") has little effect on peak performance, but the overall under prediction bias is reduced by 5-6 percentage points. Overall, UAM was relatively insensitive to the specification of a lighter domain mean wind in DWM.

Combined Effects

In the sensitivity tests discussed above, the very small performance gains in bias and (in some cases) in peak performance at East Charleston hold promise, but do not nearly approach the gains needed for satisfactory performance individually. Therefore, a test was conducted in which all of these modifications were made in UAM simultaneously. Light hourly domain mean winds were supplied to DWM from tethersonde data and the DWM was run with ten-minute measurement data. These

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light 10-minute wind fields were supplied to UAM configured with 10 layers.

An interesting response is shown in Figure 21, a plot of hourly maximum predicted CO for this case. While the 9 ppm cloud in the East Charleston area is larger than any previous individual test, the overall maximum predicted is less than the base case (10.35 ppm vs. 10.62 ppm). From the time series showing the combined case with the Base Case (Figure 22) much higher CO is predicted overall, which should improve the underestimate bias, but the response to peak performance at East Charleston is again minimal. Some of the morning peaks are better predicted, but are still underestimated. As expected, a comparison of model performance for the combined case (denoted as “Run 11" in Table 13) with Base Case performance shows that indeed peak predictions are better modeled (15% under prediction vs. 25% under prediction in the Base Case), except for East Charleston where a modest 4 percentage point decrease is shown. Also, overall under prediction bias is reduced from over 40% to about 25%. Based on these improvements, we may strongly consider using ten-minute wind fields, generated with domain mean winds obtained from the profilers, with a ten-layer UAM structure for Phase II base case simulations.

Off-cycle Mobile Emissions

Currently, MOBILE does not include all sources of on-road vehicular CO emissions. A significant amount of CO emissions result from driving behaviors not accounted for in the model. In particular, the maximum rate of acceleration used in standard emission testing driving cycles is lower than the maximum rate observed in-use. Acceleration and other driving behavior can greatly affect the emission rate of a vehicle, especially during particular modes with extra load or enrichment. The EPA is completing work to quantify the effect that this omission is having on mobile source inventory estimates. The emissions not included in the current model’s driving cycles are commonly called “off-cycle emissions” or “in-use driving effects”. These two terms are used interchangeably.

Because the EPA OMS decided to exclude off-cycle emissions from MOBILE5b, off-cycle CO emissions were included as a sensitivity analysis. The preliminary EPA OMS methodology to treat these effects was followed exactly in modifying the MOBILE5a emission factors. This methodology is presented in Appendix A of the modeling protocol. The modified emission factors were processed through DTIM2 and EPS2 in the same manner as the base case inventory in order to get a modified emissions inventory. Daily total CO emissions (sum of mobile, area, and point) were increased by 15% in this manner.

Figure 23 shows the resulting gridded hourly peak CO concentrations. The peak CO is substantially increased throughout the grid, with an overall peak of 11.75 ppm. The area within the 9 ppm contour is much larger than the Base Case, and a rather large area above 9 ppm is also predicted along I-15/Las Vegas Blvd (between Flamingo and Sahara). Time series comparing this test with the Base Case (Figure 24) show minor increases in CO over most of the simulation period for many of the sites recording elevated CO. Performance statistics in Table 13 (denoted as “R6") show higher predicted CO and therefore better performance for the nighttime peaks than any of the meteorological/grid type sensitivity scenarios separately; however, it was still insufficient to bring peak predictions into agreement with observations (e.g., 20% average under predictions of peaks vs. 25% under prediction of peaks in the Base Case). While it is generally felt that off-cycle contributions to mobile CO emissions should be included in MOBILE5, the decision to include these effects for Phase II remains rather political.

Time Shift in Mobile Emissions

A very early test was conducted in which the diurnal distribution of mobile emissions were shifted 2-3 hours later (while the spatial distribution and daily total mobile emissions were unchanged). This was undertaken to understand the interaction between the timing of mobile emission peaks and the onset of strong stability and stagnation. In the test described here, only mobile emissions were modeled (i.e., not stationary point or area source emissions were included).

Figure 25 shows the resulting gridded hourly maximum CO distribution; the differences are significant, as the shift of the late afternoon emissions peak to early evening traps much more CO into the first layer. The overall maximum concentration predicted is 14.51 ppm (10.62 ppm Base Case), and the CO levels in the East Charleston area range 11-13 ppm. The area within the 9 ppm contour extends over much of the area between I-15 and highway 95. The resulting time series for East Charleston is stunning (Figure 26), as the predicted concentration (dashed line) trend matches observations very well. Comparison of performance statistics (Table 13, denoted as “R1g”) show remarkable improvement in peak predictions (an average over all sites of +1%) and moderate improvement in the underestimation bias. Note that the average difference in hours at which peak CO is predicted vs. observed is zero.

This test indicated the most dramatic and favorable improvements to model performance for the nightly peaks, while not impacting the morning peaks. Mobile activity profiles used in DTIM2 to distribute daily emissions to each hour of the day are based on traffic count data, and therefore moving emissions in time would be unjustified. However, inspection of hourly traffic count data at all NDOT sites throughout Las Vegas revealed that some diurnal traffic profiles are quite unique. In fact, the profile on Las Vegas Boulevard deviated significantly from other traffic count sites and from the average profile that was used in the emissions modeling. This site indicated a substantial volume of traffic into the evening hours. We propose for Phase II modeling, therefore, that DTIM2 be run for sub-grids that are represented by each NDOT traffic count site so that mobile emissions within each sub-area can be appropriately distributed in time. It would then be a simple matter of combining all sub-areas into a final gridded hourly emissions file.

Stable Afternoon

It was suggested that a test be conducted in which the atmosphere is stabilized much earlier than 5 PM in the Base Case to see if peak CO emissions at 3-4 PM (as given by the annual average diurnal activity profiles) are sufficiently trapped and contribute to peaks at East Charleston later in the evening. Indeed a significant increase in the spatial distribution of hourly maximum CO resulted (Figure 27), particularly at McCarran Airport where an overall maximum of 15.46 ppm was predicted. Inspection of the time series in Figure 28 is more revealing, however. This test resulted in over predictions of the CO buildup at East Charleston and many other sites in the early evening

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and did not lead to an improvement of the predicted peak CO later in the evening or the CO peaks in the morning. This is shown in Table 13 as well (denoted as “R5"), where peak predictions at East Charleston improved from a 30% under prediction to only a 23% under prediction, and the time of the predicted peak moved earlier by 1 hour. While overall under prediction bias was improved from 41% to 25%, the gross error increased from 45 to 48%, which indicates worse accuracy.

CONCLUSIONS FROM PHASE I UAM CO MODELING

The findings and conclusions of the Base Case and sensitivity cases are reiterated here for purposes of summary.

Base Case

- Overall, the UAM predicts a similar pattern to that measured, including the peak CO in the East Charleston area, elevated CO near the center of Las Vegas and along the southeastern extent of highway 95, and markedly lower CO levels in outlying areas.
- For sites with elevated CO, UAM tracks the time evolution of CO fairly well, but consistently under predicts, particularly several observed mid morning peaks. The range of CO predicted in nearby cells is often sufficient to bring UAM into closer agreement with observations, except in the morning hours (5-9 AM).
- The UAM does not capture the peak observed CO at East Charleston, whether on a space-paired basis (30% under prediction at the measurement site), or on an unpaired basis (10% under prediction using peak anywhere in the grid).
- Peak statistics are at the upper limit or outside of the EPA guidance for acceptable model performance. Note, however, that UAM does a good job at replicated when the peaks occur, where the average difference in time of modeled vs. observed peaks is only one hour.
- UAM performance is promising in that the evolution of the Las Vegas CO cloud, subsequent transport, and intensification agree with our conceptual model based on observations, knowledge of emission patterns, and previous field work.

10-Layer Test

- The model indicates very little sensitivity to this rather drastic modification of vertical structure; the most notable effects result from removing the artificial dilution occurring from a deepening of the inversion depth during these hours.
- However, these improvements are insignificant, and result in only a minimal improvement to important performance statistics.
- Overall, these results strengthen the argument that the depth of the surface layer controls predicted CO concentrations as most emissions are emitted into this layer at night and do not mix vertically.
- The UAM, regardless of the vertical structure specified, is therefore reduced to a single surface layer model as it implies a vertically uniform CO distribution through 20-40 m.

10-Minute Wind Test

- Differences in the peak CO were minimal, but the larger area of highest predicted CO in the East Charleston area suggests that the use of 10-minute winds in that area maintain and build up the CO cloud rather than transport it away.
- Performance statistics indicated only marginal improvement, similar to the 10-layer case.
- Overall, results are inconclusive, but the signal found in peak performance at East Charleston and other sites, and to the size of the predicted CO cloud in that vicinity, are consistent with our ideas that hourly inputs are not adequate to properly characterize stagnation events.

Light Domain Mean Wind Test

- Although the overly stagnant wind field was deemed to be inadequate as the optimal field for the base case UAM simulation, it was used in a UAM sensitivity test as another evaluation of model performance response to input winds.
- The largest differences were expected and predicted to occur in areas of the grid removed from meteorological observation sites, where the gridded winds are dominated by the specification of the domain mean wind.
- As gridded winds in the East Charleston area are dominated by the surface observations and the tethersonde data, minimal sensitivity was found in that area.
- This case had little effect on peak performance, but the overall under prediction bias was reduced by 5-6 percentage points.
- Overall, UAM was relatively insensitive to the specification of lighter domain mean wind in DWM.

Combined Test

- Peak predictions are better modeled than the Base Case, except for East Charleston where a modest improvement is shown.
- Overall under prediction bias is reduced from over 40% to about 25%
- Based on these improvements, we may strongly consider using ten-minute wind fields, generated with domain mean winds obtained from the profilers, with a ten-layer UAM structure for Phase II base case simulations.

Off-cycle Mobile Emissions Test

- Daily total CO emissions (sum of mobile, area, and point) were increased by 15% when off-cycle mobile emissions were added.
- Performance statistics show higher predicted CO and therefore better performance for the nighttime peaks than any of the meteorological/grid type sensitivity scenarios separately; however, it was still insufficient to bring peak predictions into agreement with observations.
- While it is generally felt that off-cycle contributions to mobile CO emissions should be included in MOBILE5, the decision to include these effects for Phase II remains rather political.

Time-Shifted Mobile Emissions Test

- Indicated the most dramatic and favorable improvements to model performance for the nightly peaks, while not impacting the morning peaks.
- Mobile activity profiles used in DTIM2 to distribute daily emissions to each hour of the day are based on traffic count data, and therefore moving emissions in time would be unjustified.
- We propose for Phase II modeling, therefore, that DTIM2 be run for sub-grids that are represented by each NDOT traffic count site so that mobile emissions within each sub-area can be appropriately distributed in time.

Stable Afternoon Test

- Resulted in over predictions of the CO buildup at East Charleston and many other sites in the early evening and did not lead to an improvement of the predicted peak CO later in the evening or the CO peaks in the morning.
- While overall under prediction bias was improved from 41% to 25%, the gross error increased from 45 to 48%, which indicates worse accuracy.

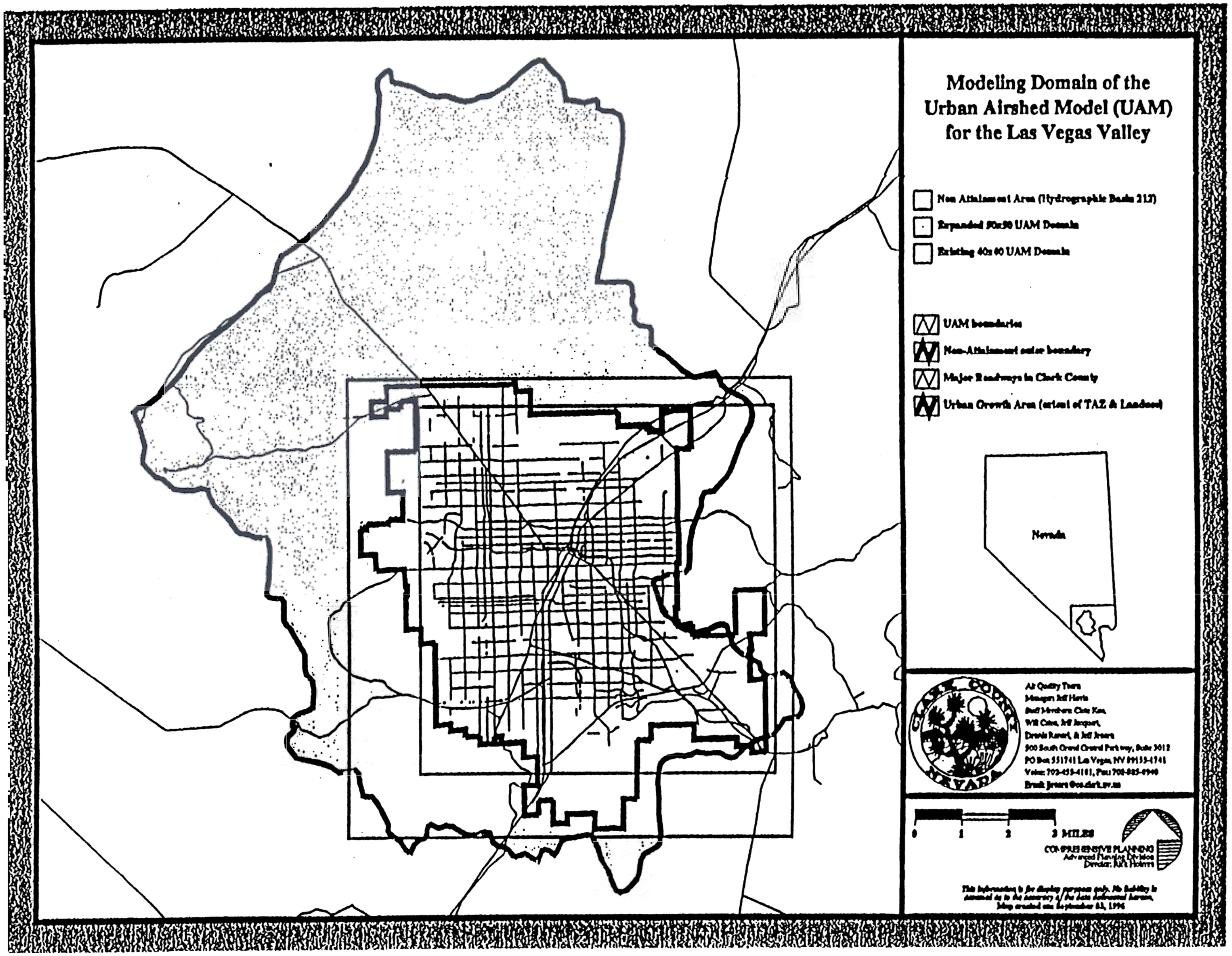

Figure 1. Map of Las Vegas showing the nonattainment boundary (outermost bold line), the original UAM CO grid extent (small square inset), and the current UAM CO grid (larger square inset).

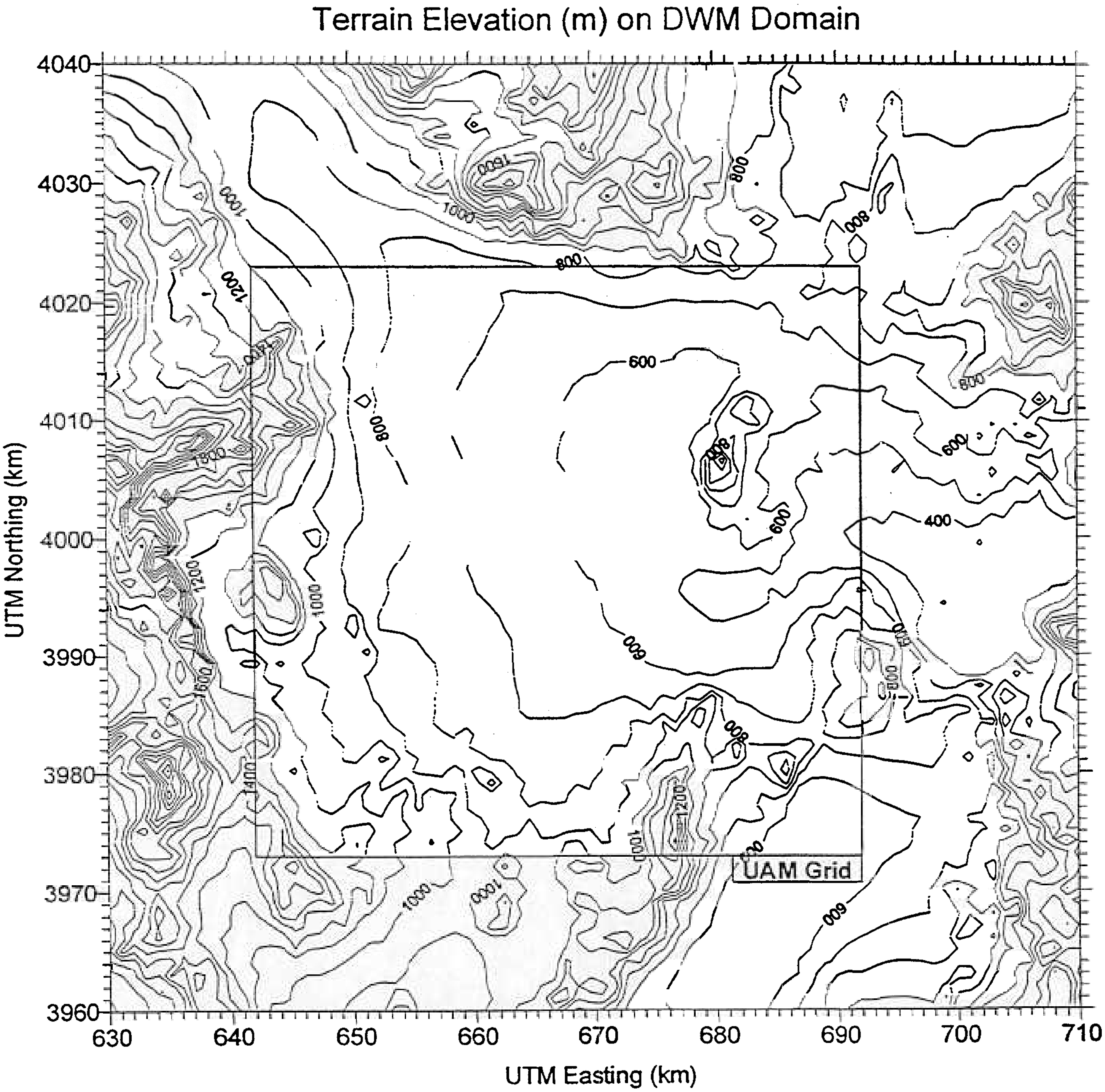

Figure 2. Map of the DWM domain with the UAM CO grid shown as inset. Grid cell size is 1 km; terrain contours given every 100 m.

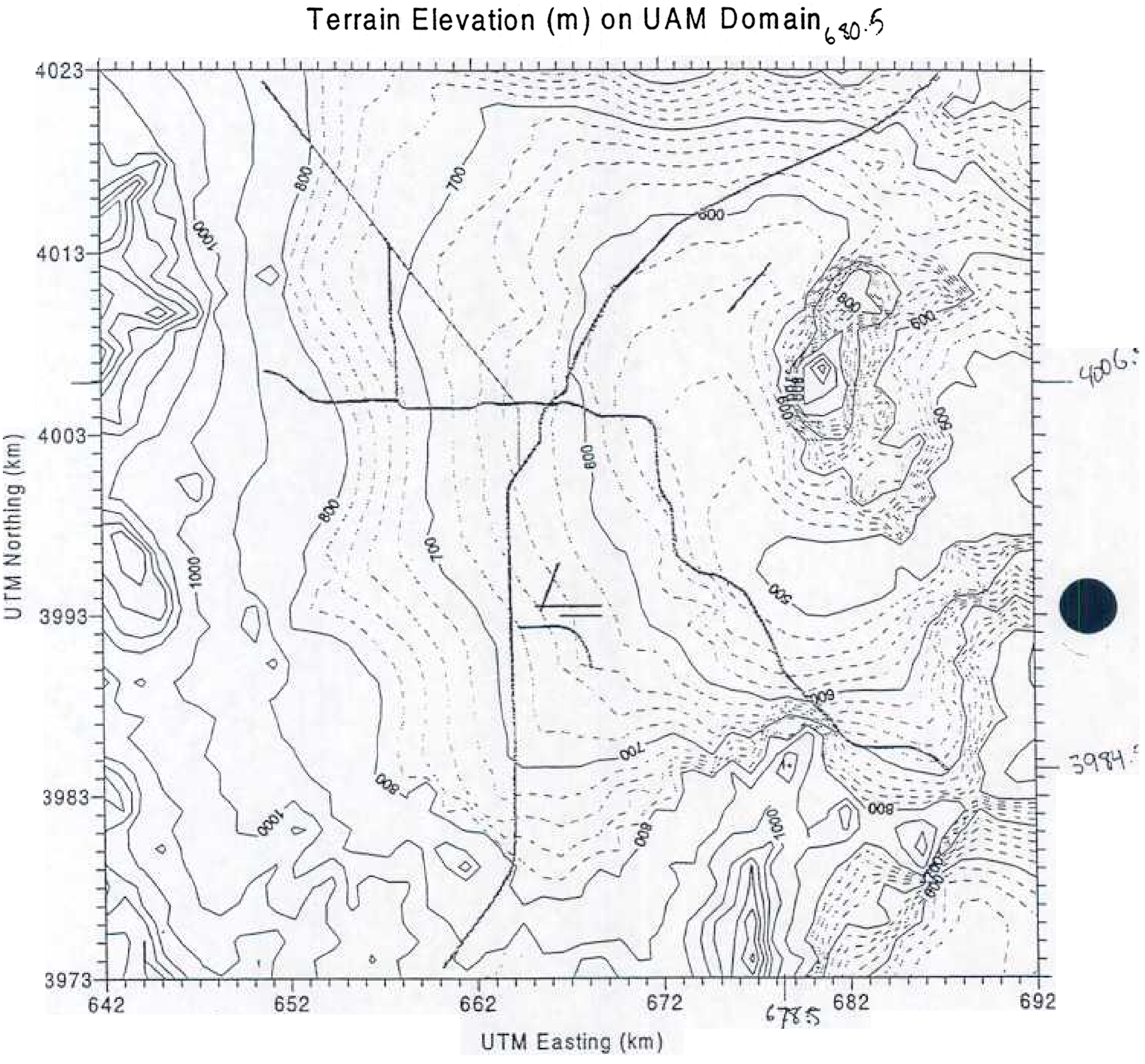

Figure 3a. Map of the UAM CO domain showing major highways and airports. Grid cell size is 1 km; terrain contours given every 100 m (solid lines) and 20 m (light dashed lines).

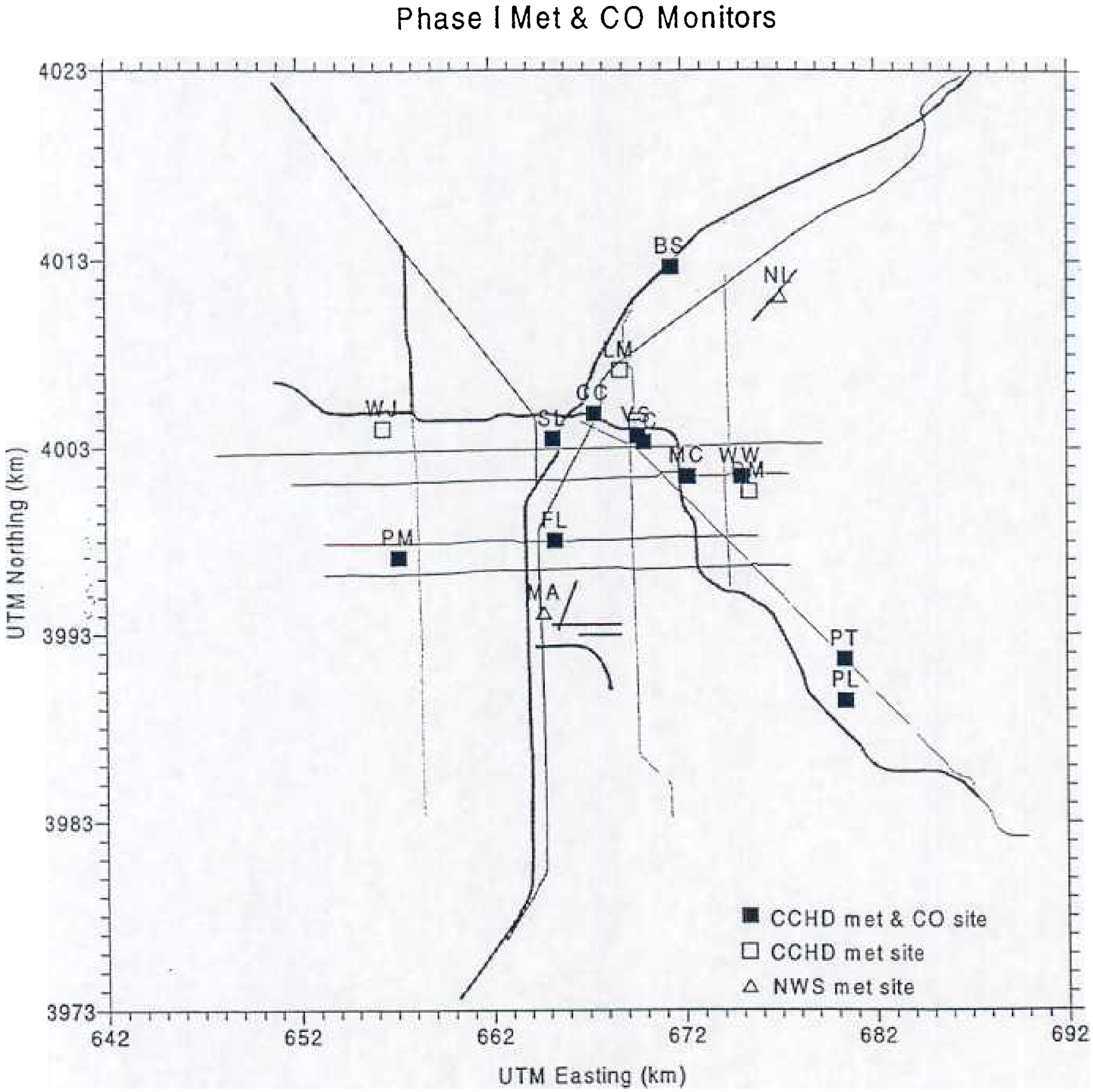

Figure 3b. Map of the UAM CO domain showing major traffic links, airports, and locations of APCD and NWS measurement sites.

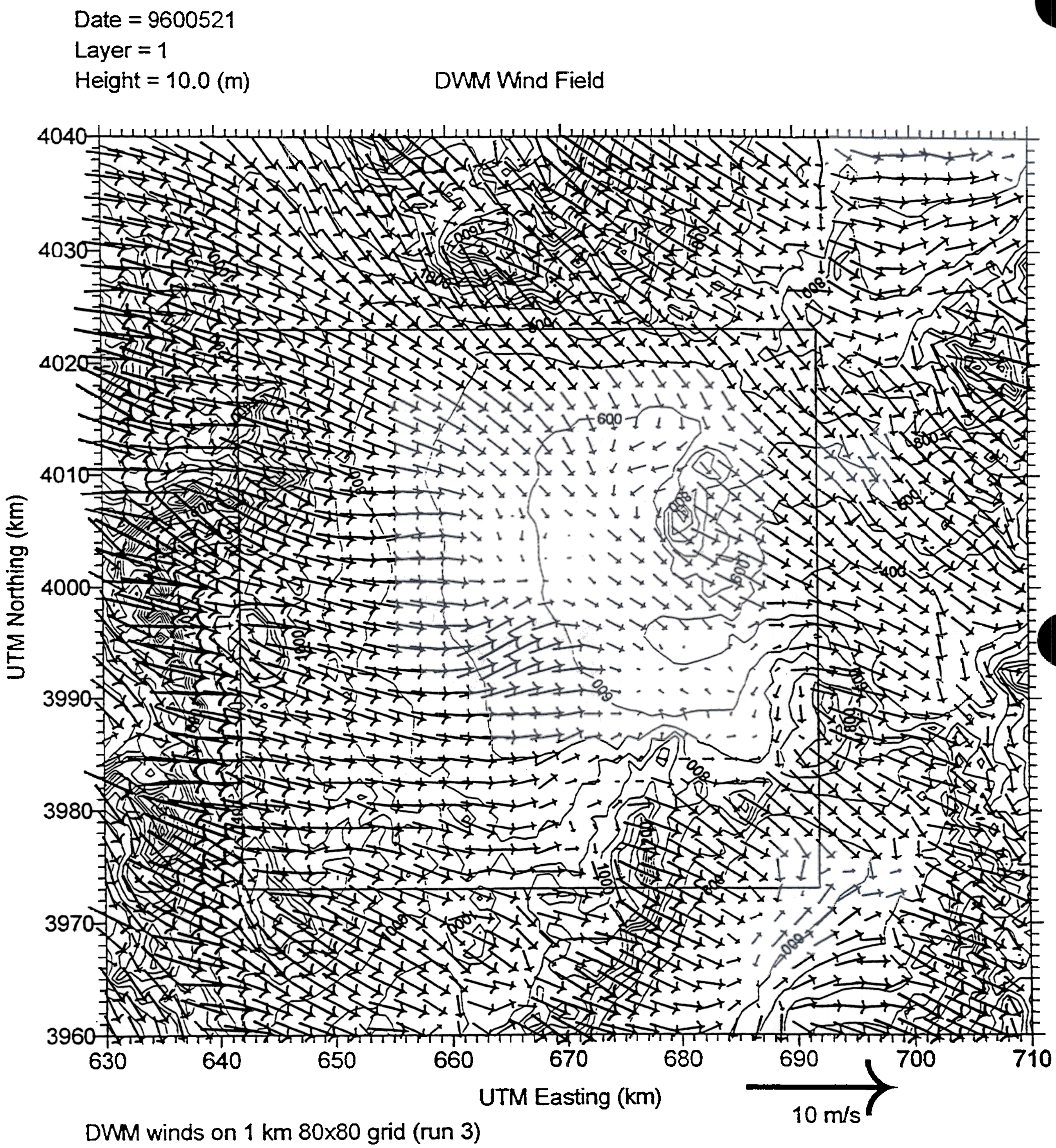

Figure 4a. An example of the base case DWM wind field in the first model layer (first 20 m above the surface) for 2100 LST (9 PM) January 5, 1996. Arrow direction indicates direction of flow, while arrow length indicates wind speed. A 10 m/s wind speed arrow is shown for reference.

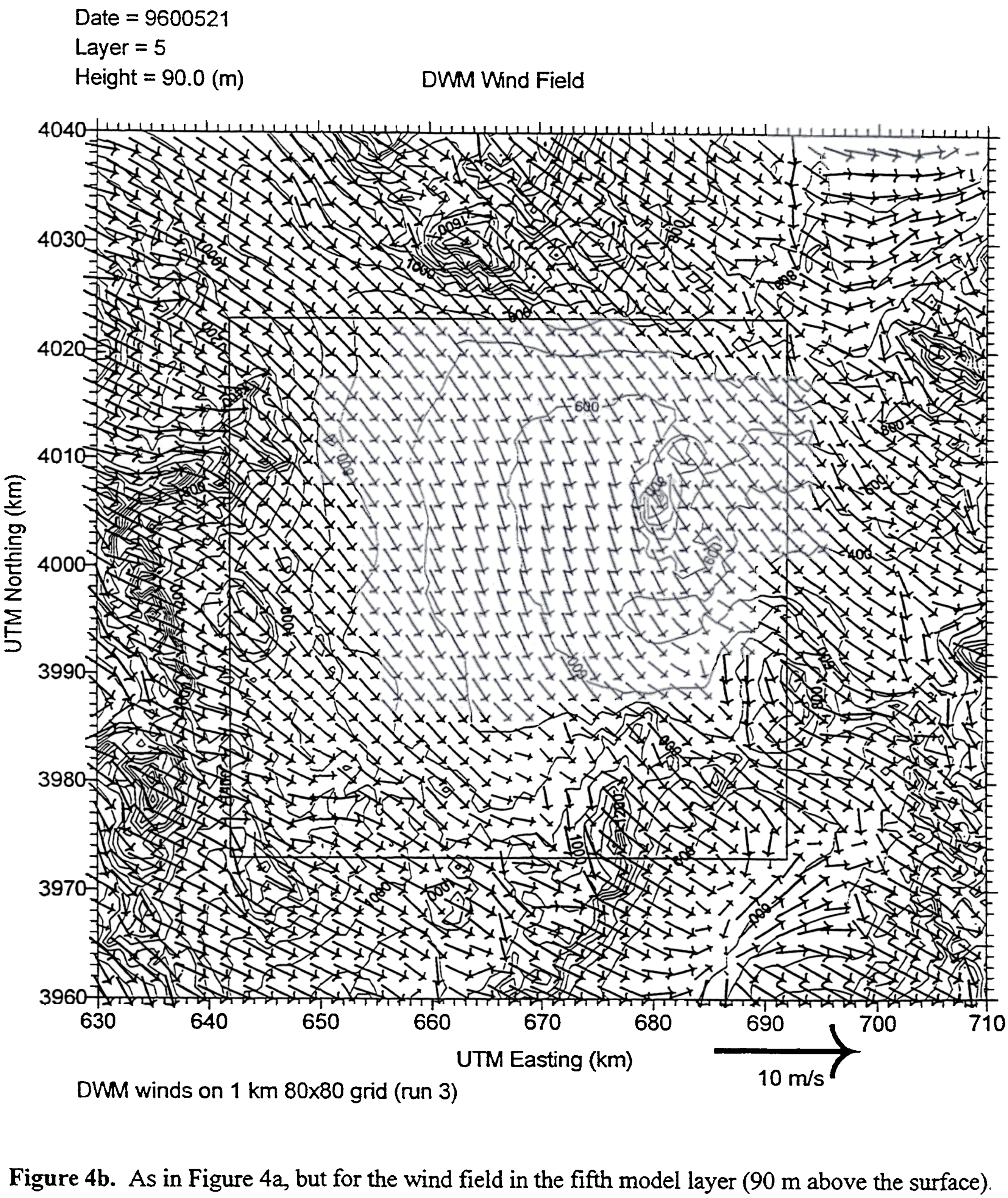

Figure 4b. As in Figure 4a, but for the wind field in the fifth model layer (90 m above the surface).

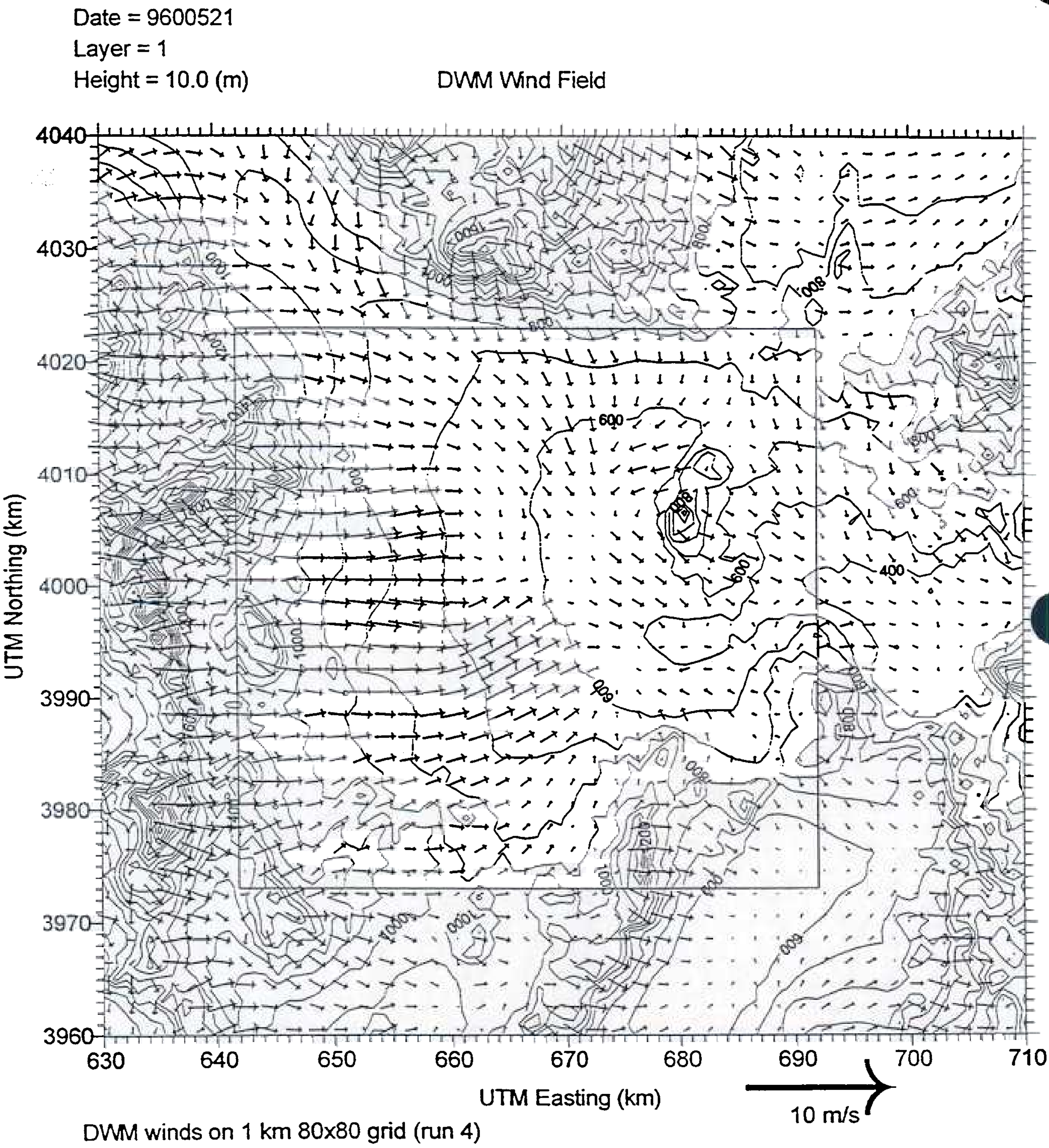

Figure 5a. An example of the light case DWM wind field in the first model layer (first 20 m above the surface) for 2100 LST (9 PM) January 5, 1996. Arrow direction indicates direction of flow, while arrow length indicates wind speed. A 10 m/s wind speed arrow is shown for reference.

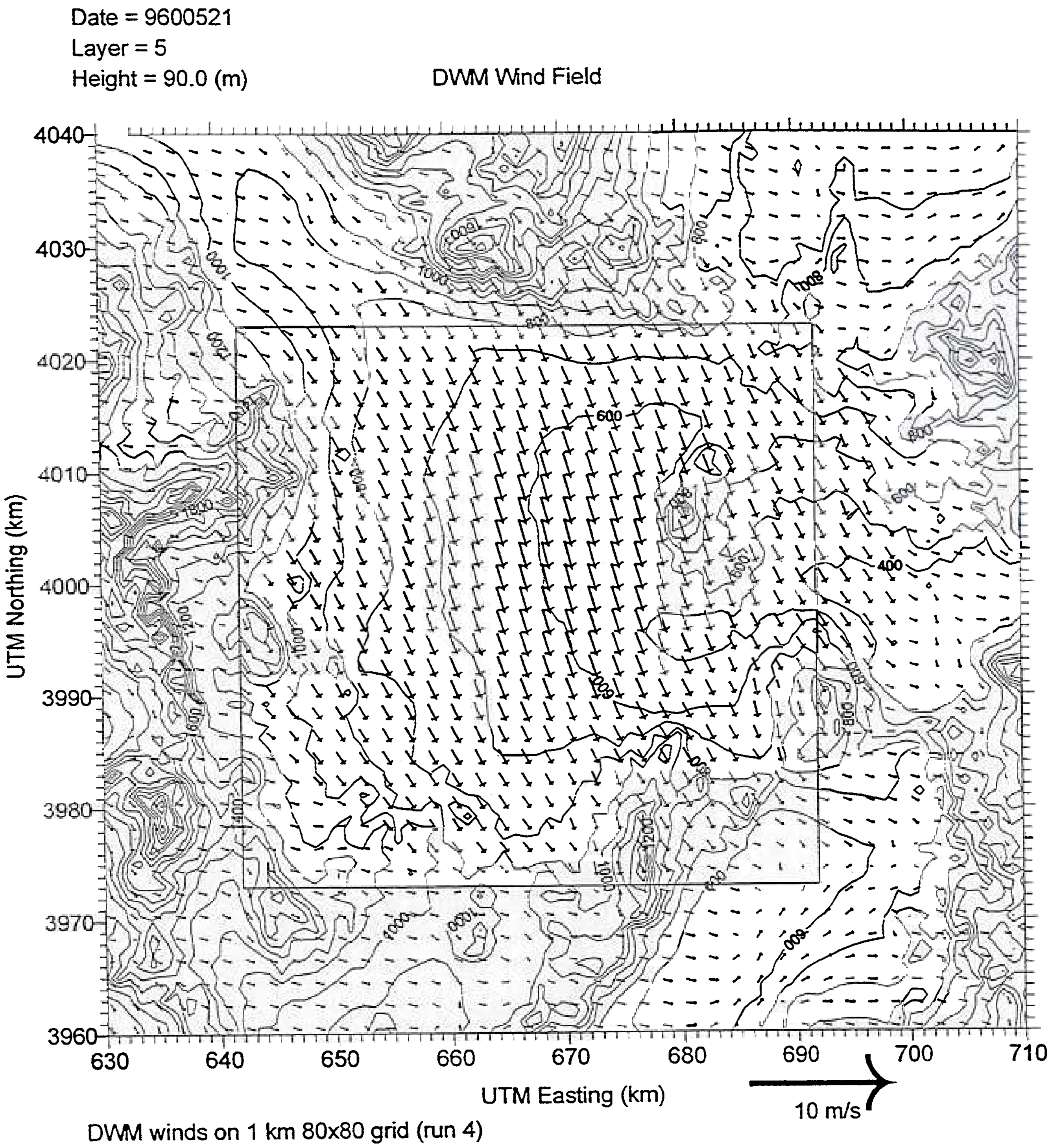

Figure 5b. As in Figure 5a, but for the wind field in the fifth model layer (90 m above the surface).

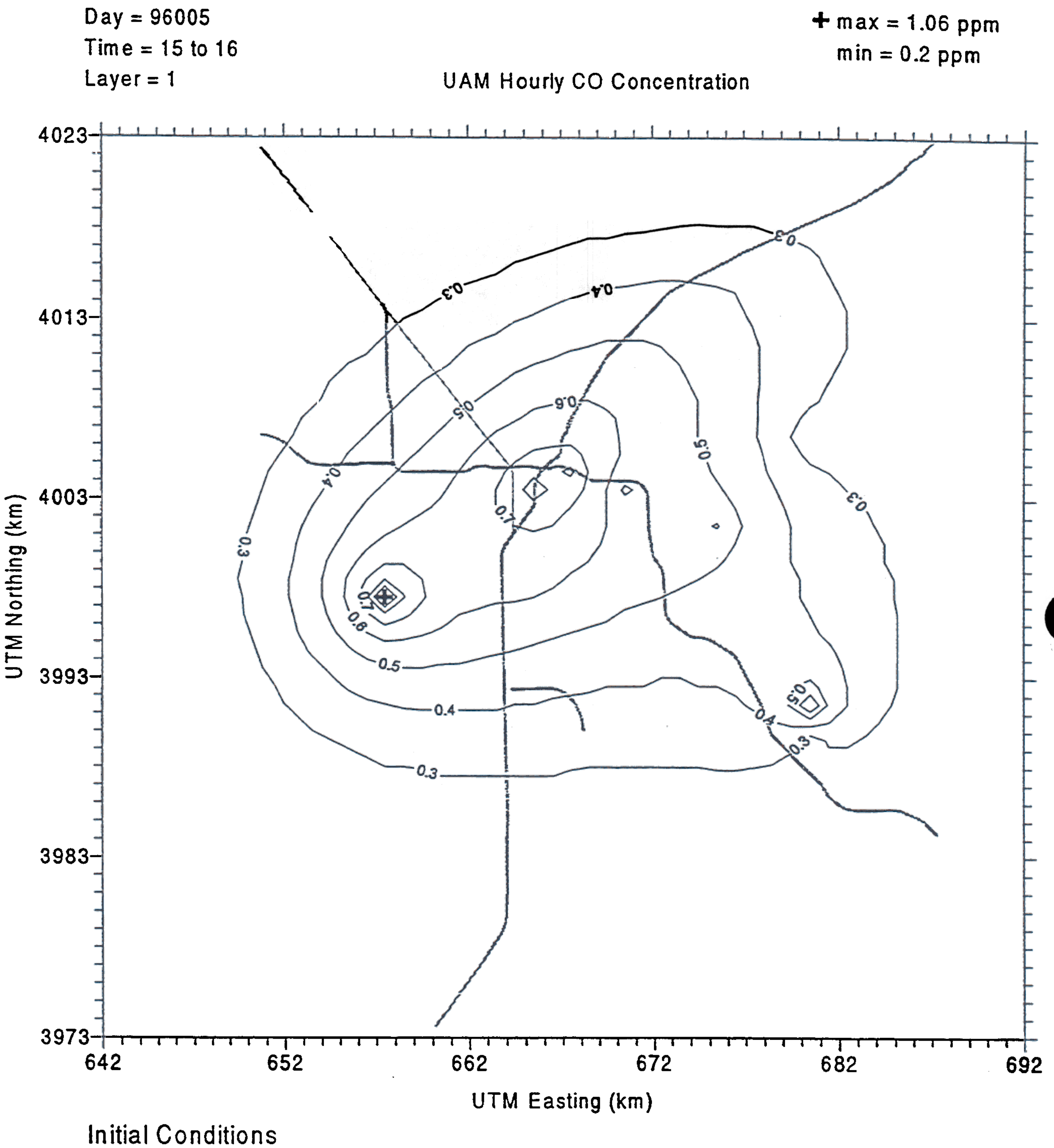

Figure 6. The spatial distribution of initial CO concentrations (ppm) supplied to the UAM in all simulations. This field is valid for 1500-1600 LST January 5, 1996. Contours are given every 0.1 ppm.

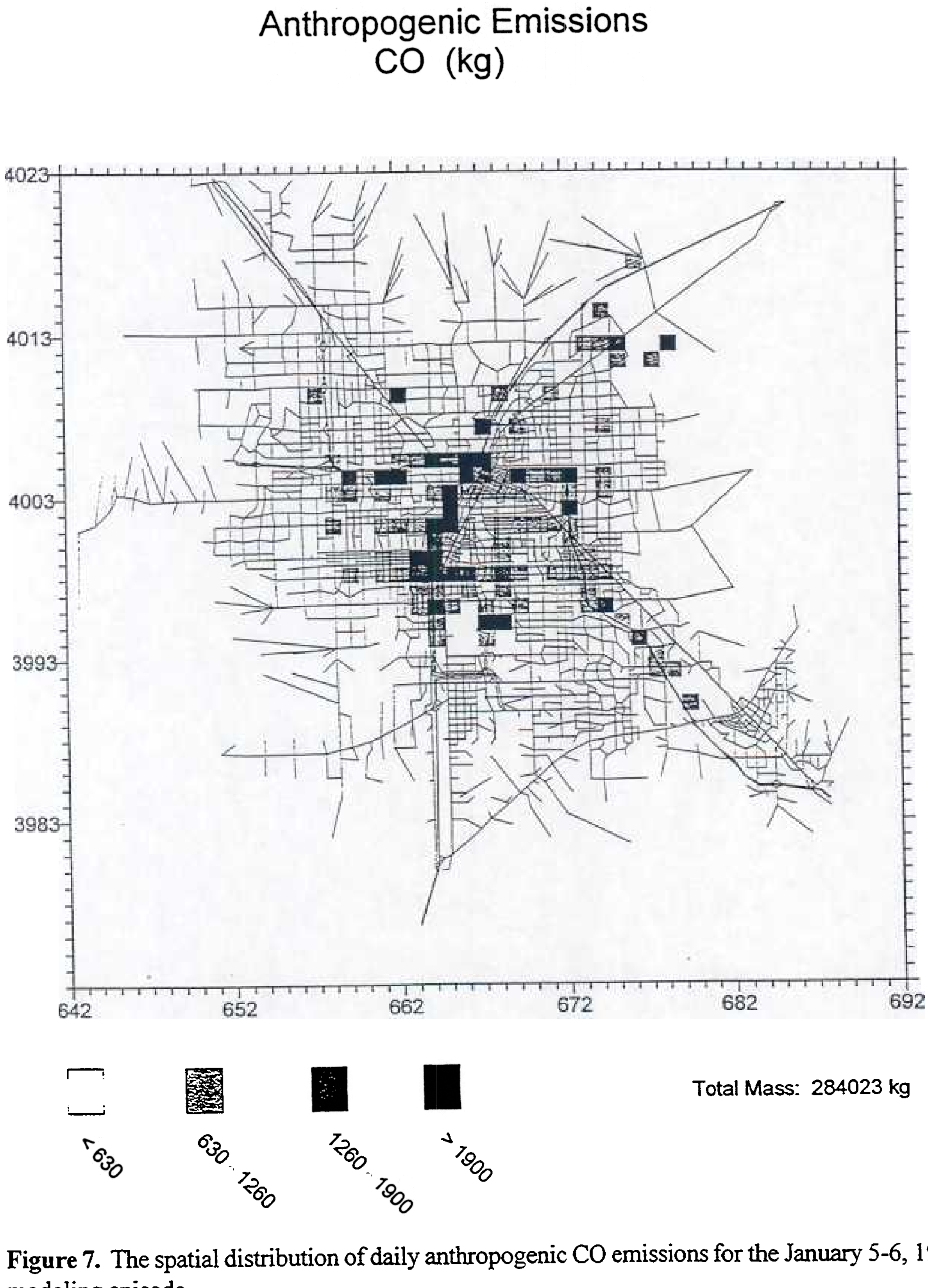

Figure 7. The spatial distribution of daily anthropogenic CO emissions for the January 5-6, 1996 UAM modeling episode.

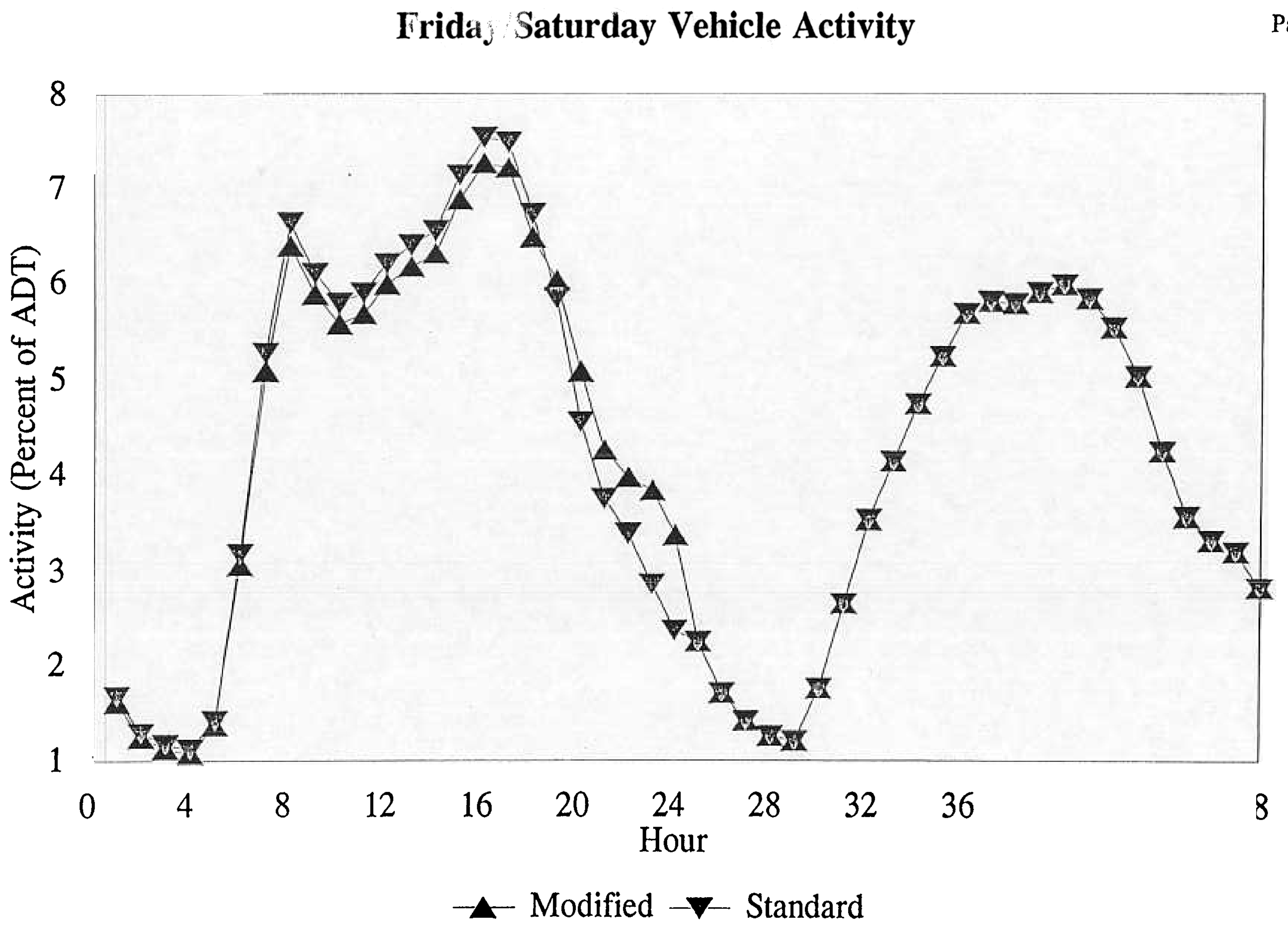

Figure 8. The diurnal profile of on-road mobile sources.

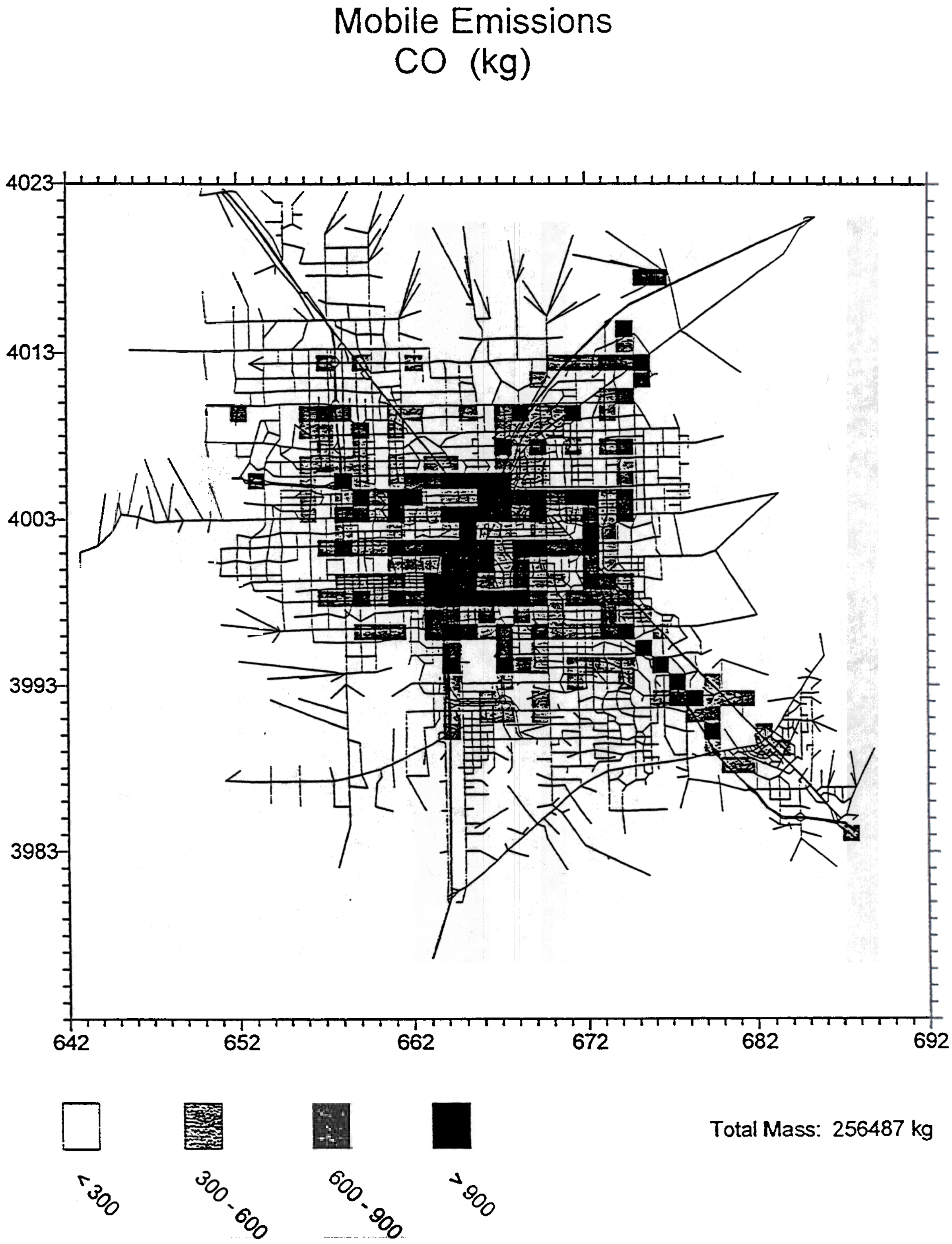

Figure 9. The spatial distribution of daily on-road mobile source CO emissions for the January 5-6, 1996 UAM modeling episode.

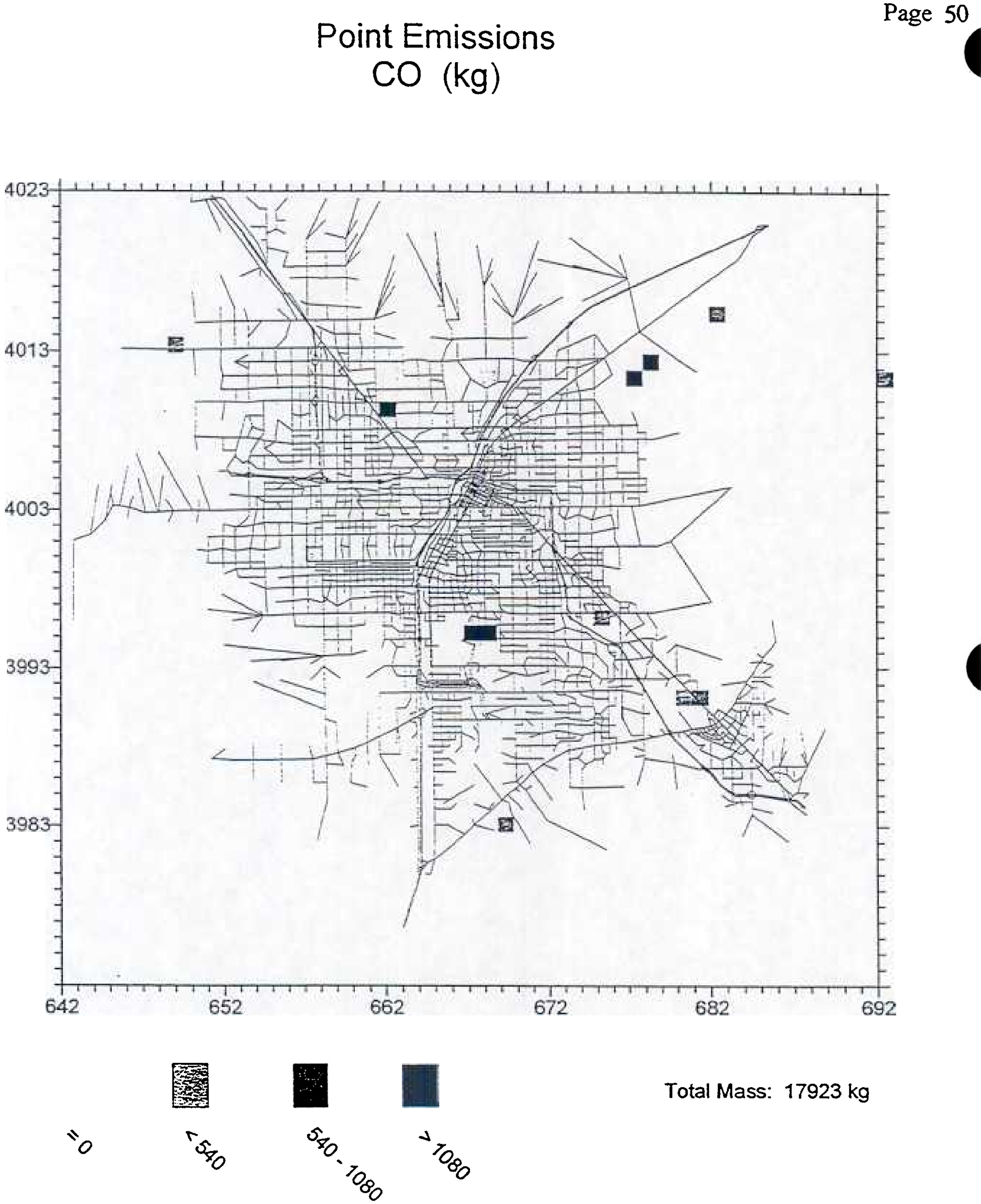

Figure 10. The spatial distribution of daily point source CO emissions for the January 5-6, 1996 UAM modeling episode.

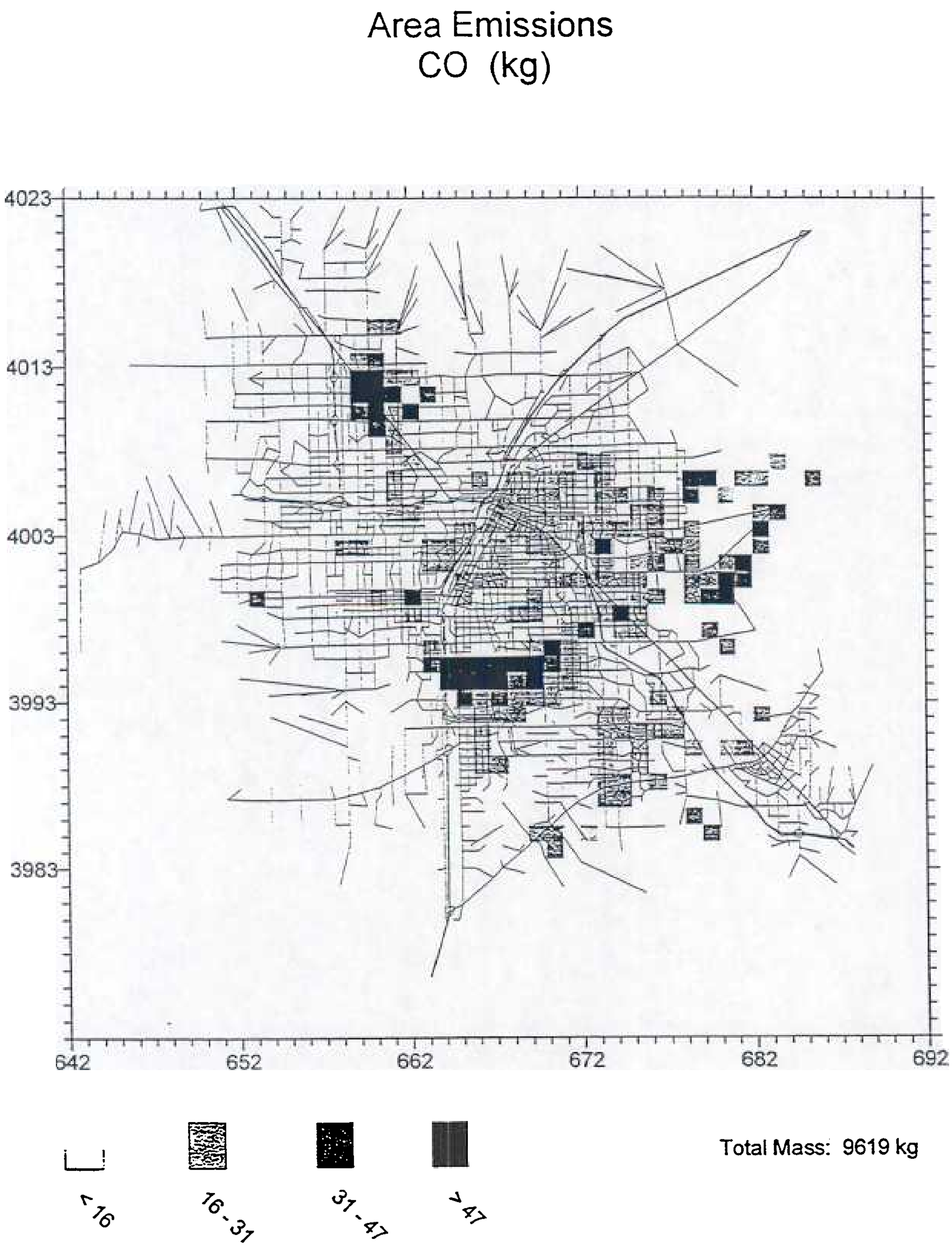

Figure 11. The spatial distribution of daily area source CO emissions for the January 5-6, 1996 UAM modeling episode.

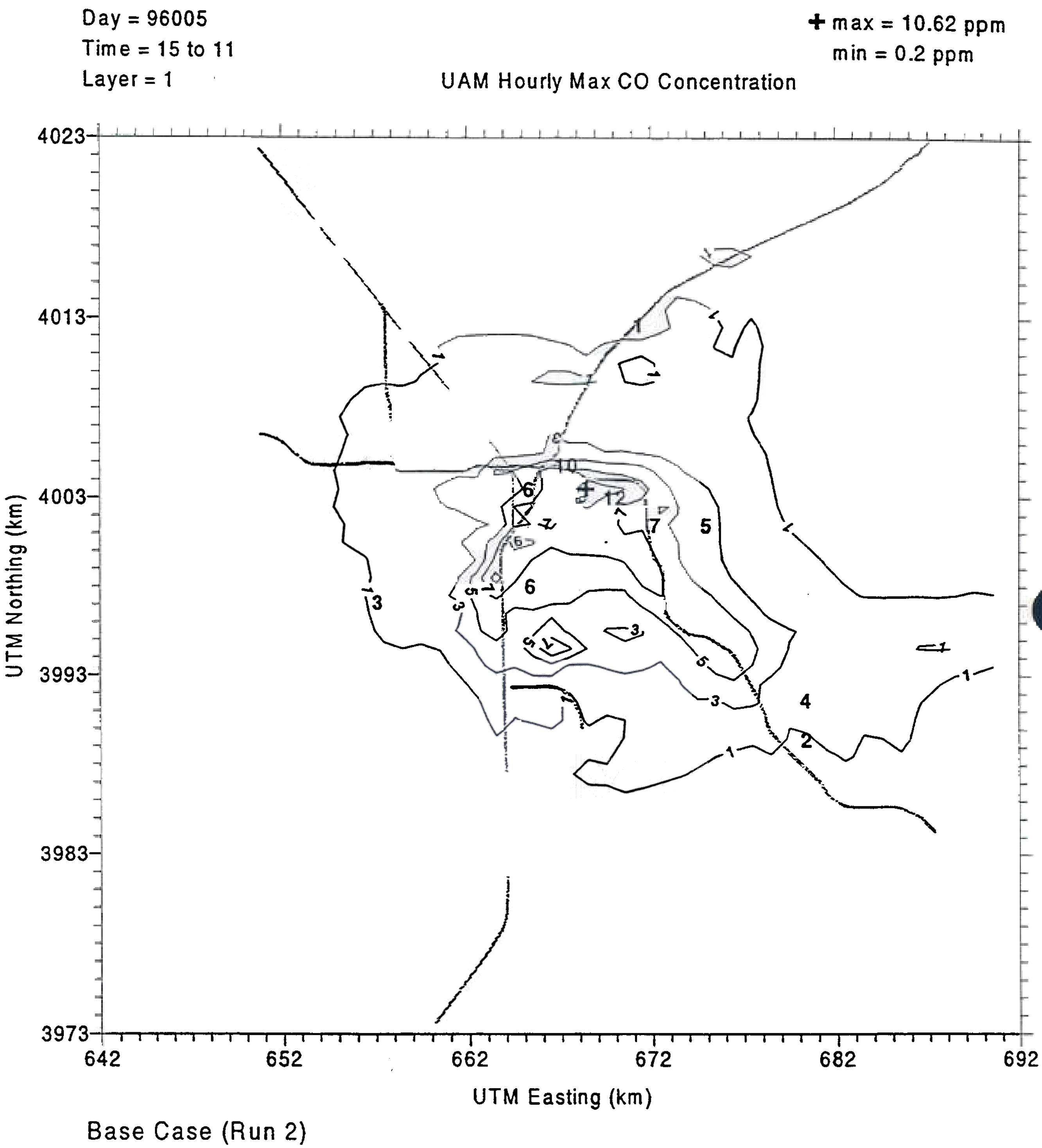

Figure 12. The spatial distribution of UAM predicted hourly maximum CO (ppm) in the Base Case. Contours are given every 1 ppm. Peak hourly observed CO (ppm) are overlaid at locations of APCD monitoring sites.

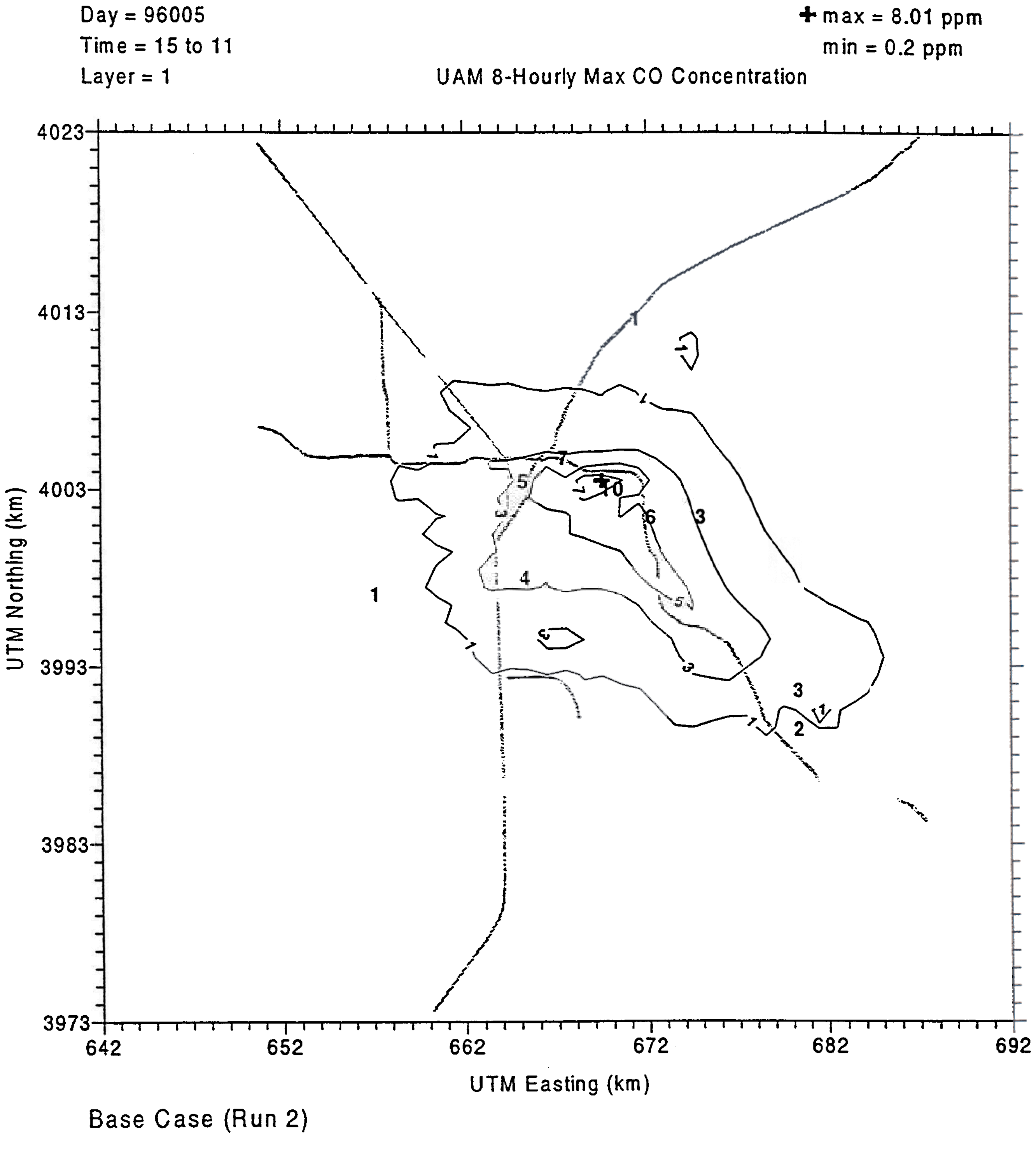

Figure 13. The spatial distribution of UAM predicted 8-hourly maximum CO (ppm) in the Base Case. Contours are given every 1 ppm. Peak 8-hourly observed CO (ppm) are overlaid at locations of APCD monitoring sites.

LVCO Base Case (Run 2); Hourly Time Series

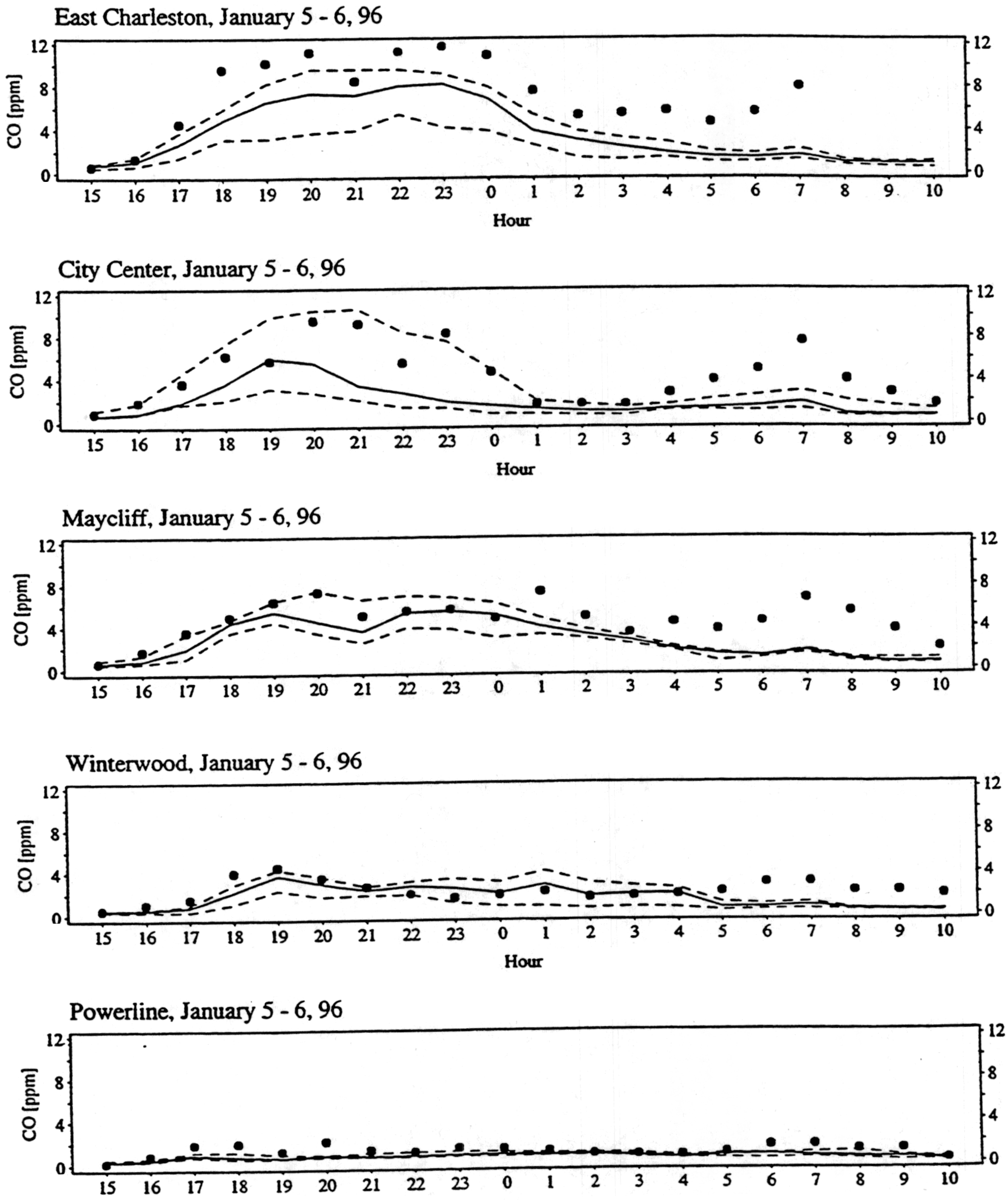

Figure 14. Time series plots of UAM predicted hourly CO (ppm) in the Base Case (solid line), and hourly observations (heavy dots) at APCD monitoring sites. The maximum and minimum concentrations predicted in the nine grid cells surrounding the locations of the monitoring sites are given as well (dashed lines).

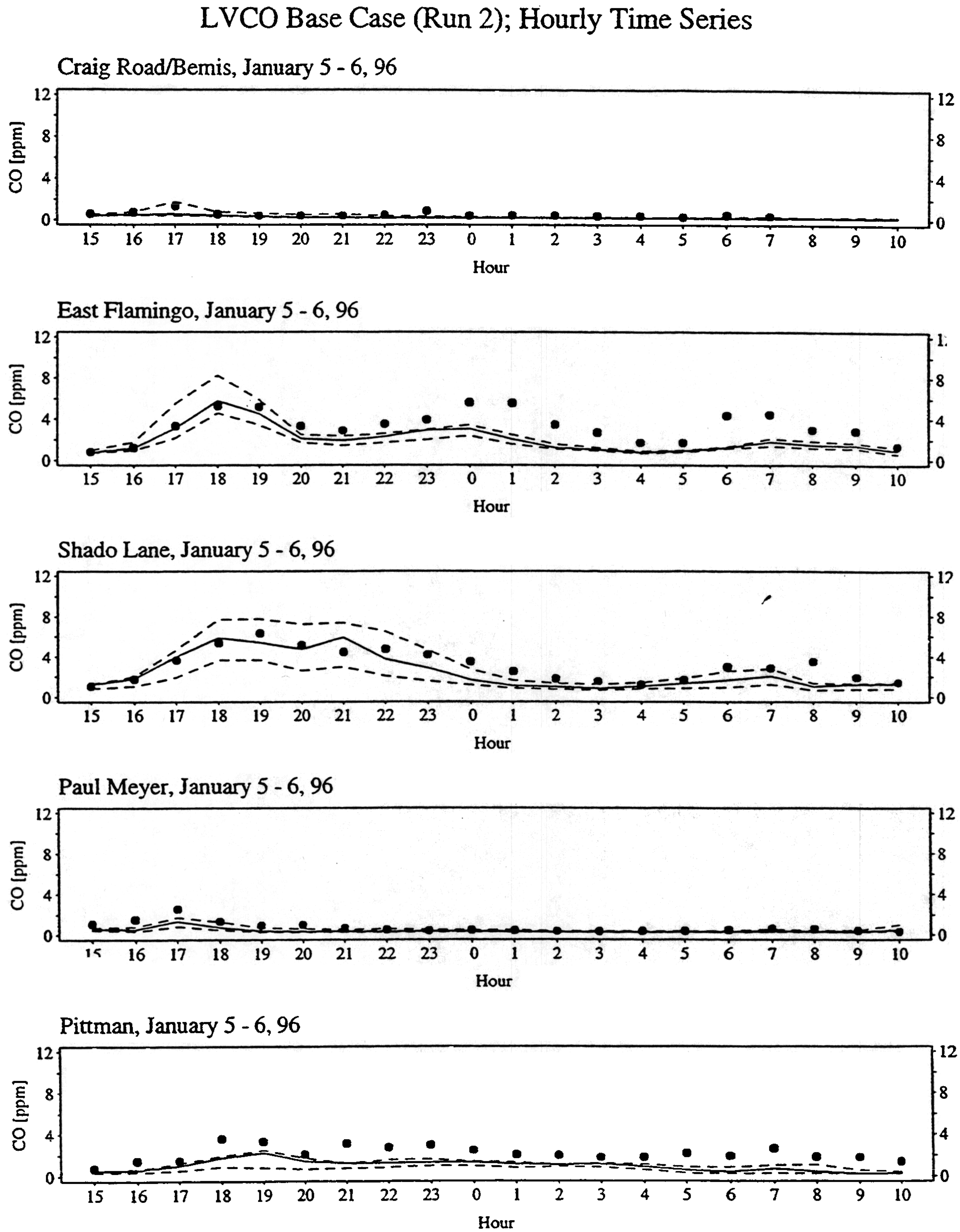

Figure 14. Continued.

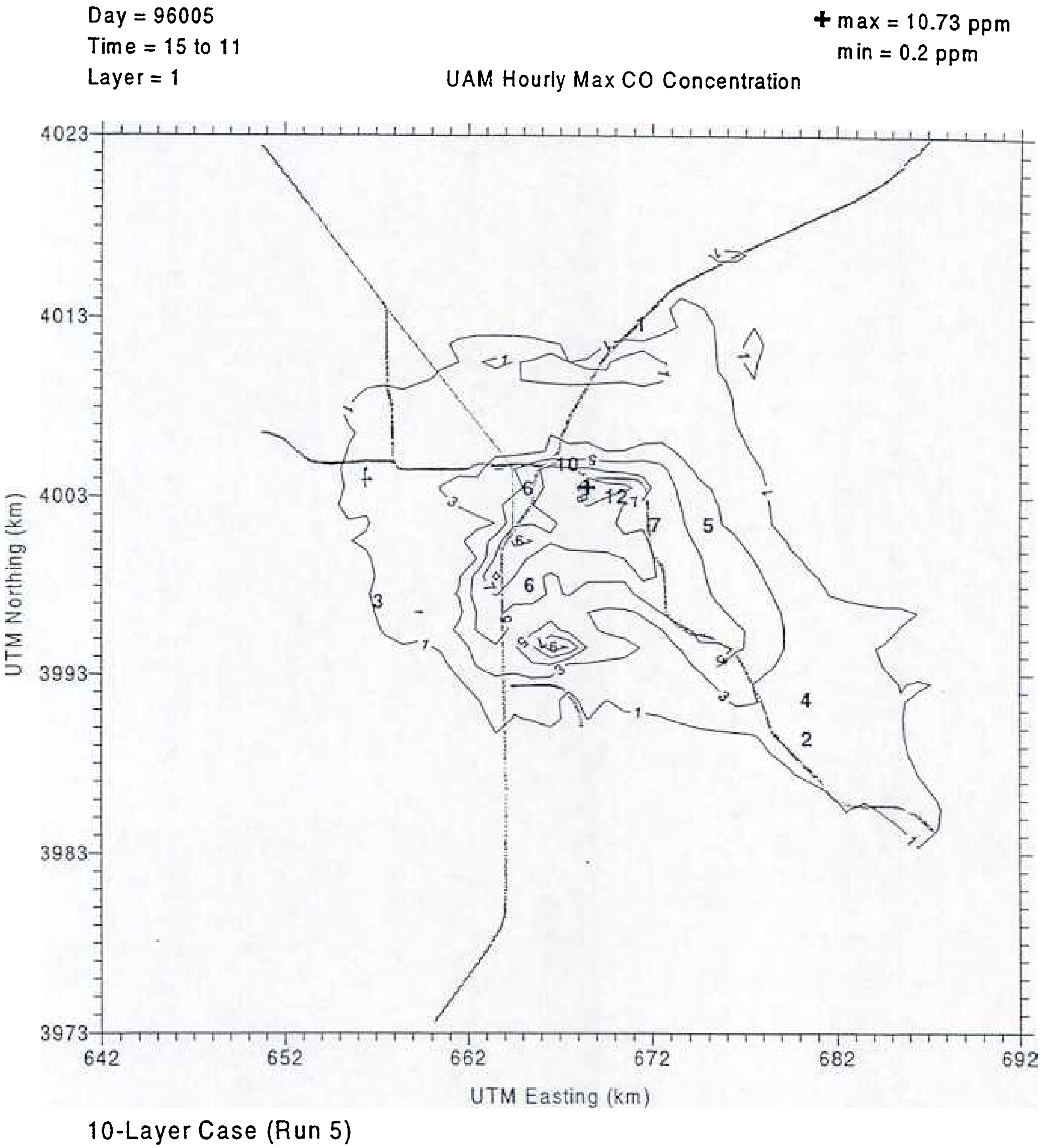

Figure 15. The spatial distribution of UAM predicted hourly maximum CO (ppm) in the 10-Layer Case. Contours are given every 1 ppm. Peak hourly observed CO (ppm) are overlaid at locations of APCD monitoring sites.

LVCO Base Case (Run 2) and 10-Layer Case (Run 5)

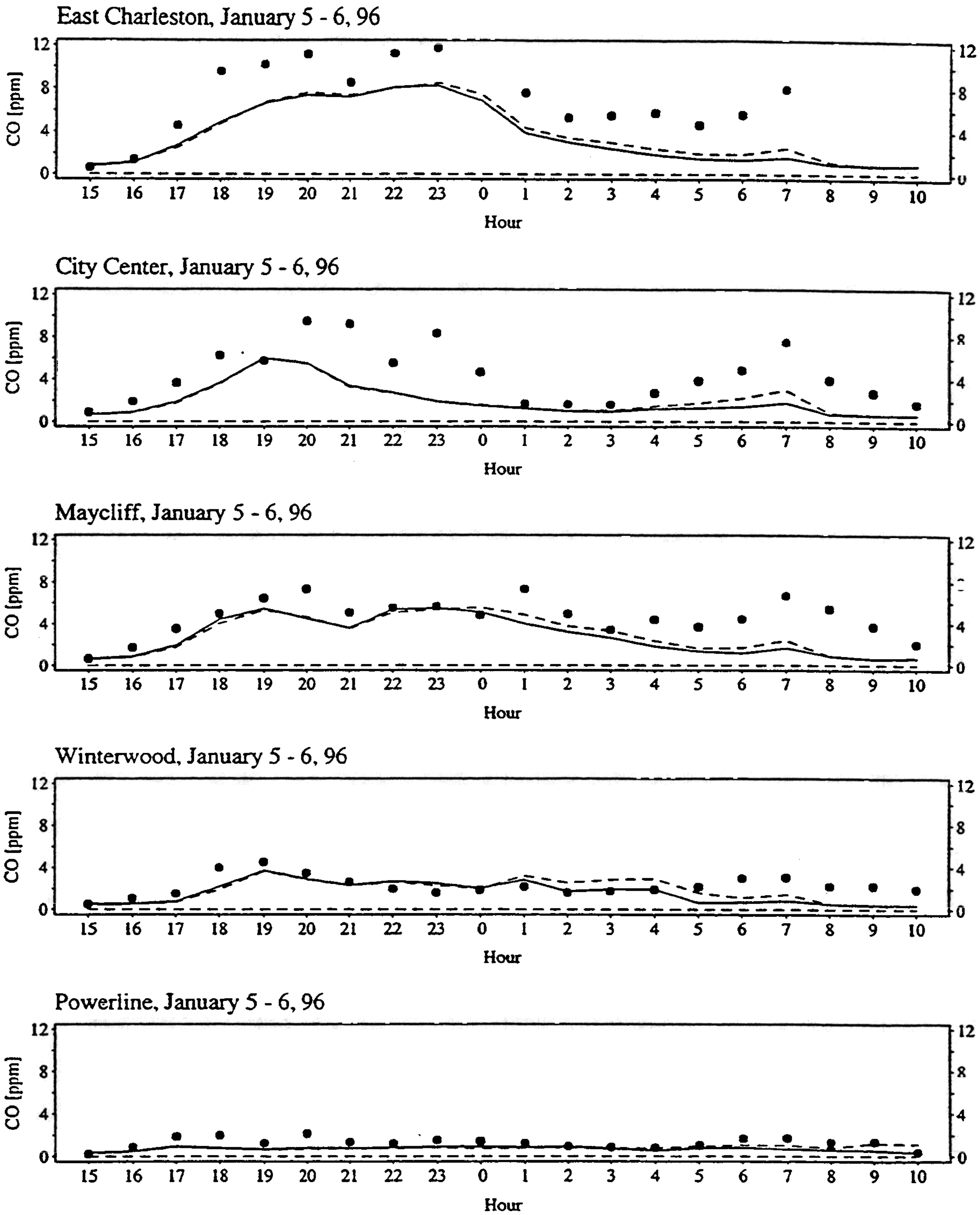

Figure 16. Time series plots comparing UAM predicted hourly CO (ppm) in the Base Case (solid line) and in the 10-Layer Case (dashed line). Hourly observations at APCD monitoring sites are indicated by the heavy dots.

LVCO Base Case (Run 2) and 10-Layer Case (Run 5)

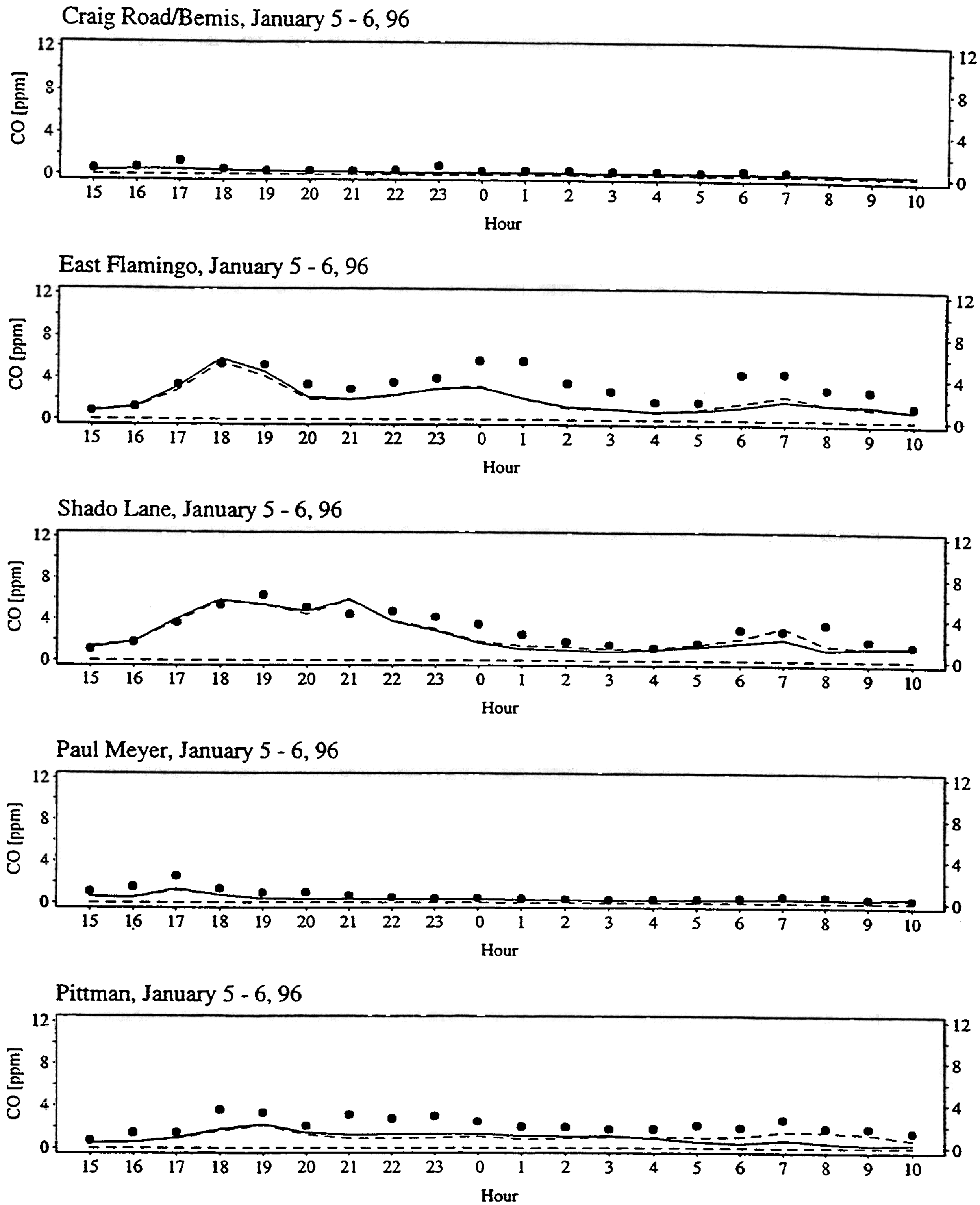

Figure 16. Continued.

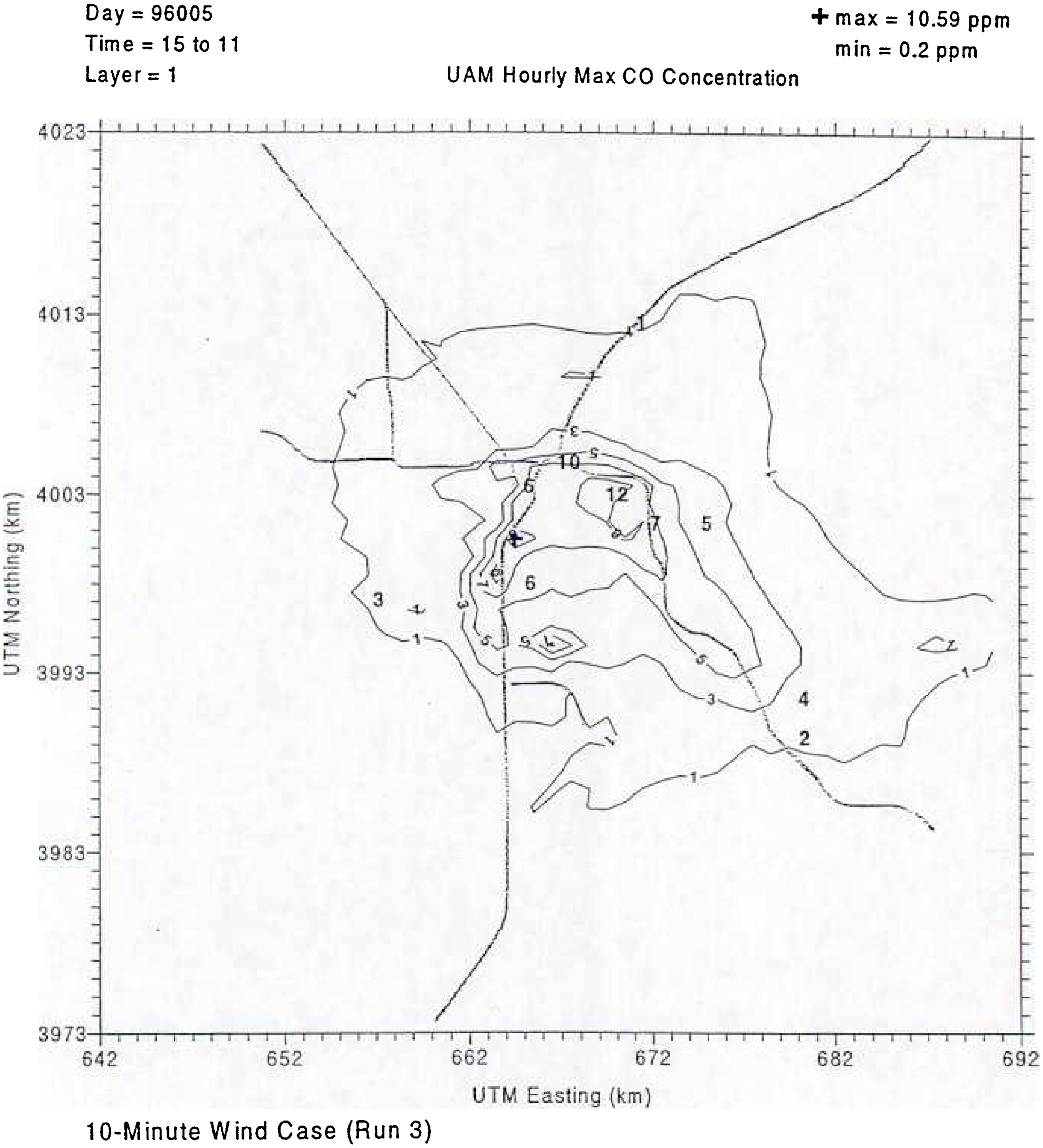

Figure 17. The spatial distribution of UAM predicted hourly maximum CO (ppm) in the 10-Minute Wind Case. Contours are given every 1 ppm. Peak hourly observed CO (ppm) are overlaid at locations of APCD monitoring sites.

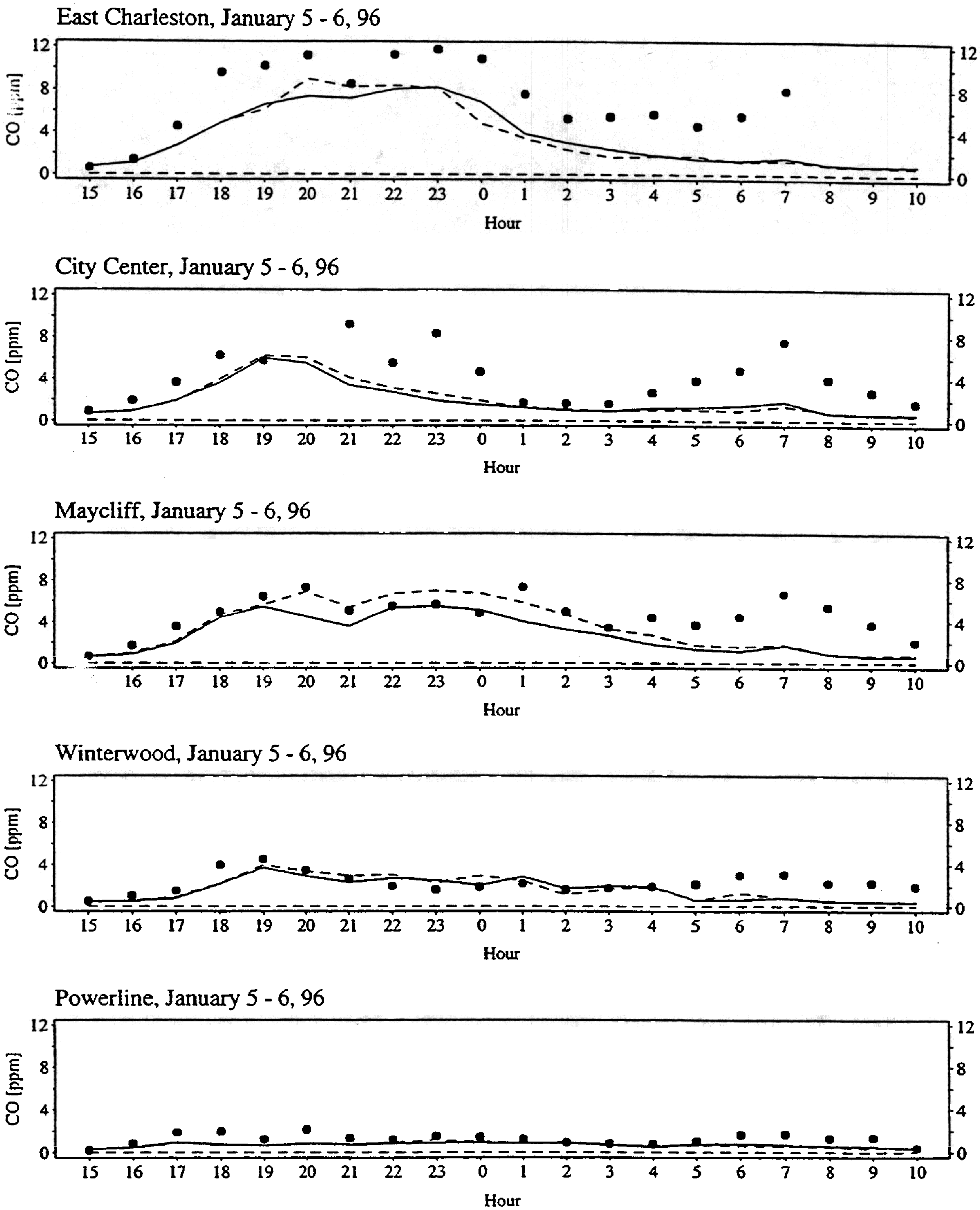

Figure 18. Time series plots comparing UAM predicted hourly CO (ppm) in the Base Case (solid line) and in the 10-Minute Wind Case (dashed line). Hourly observations at APCD monitoring sites are indicated by the heavy dots.

LVCO Base Case (Run 2) and 10-Minute Wind Case (Run 3)

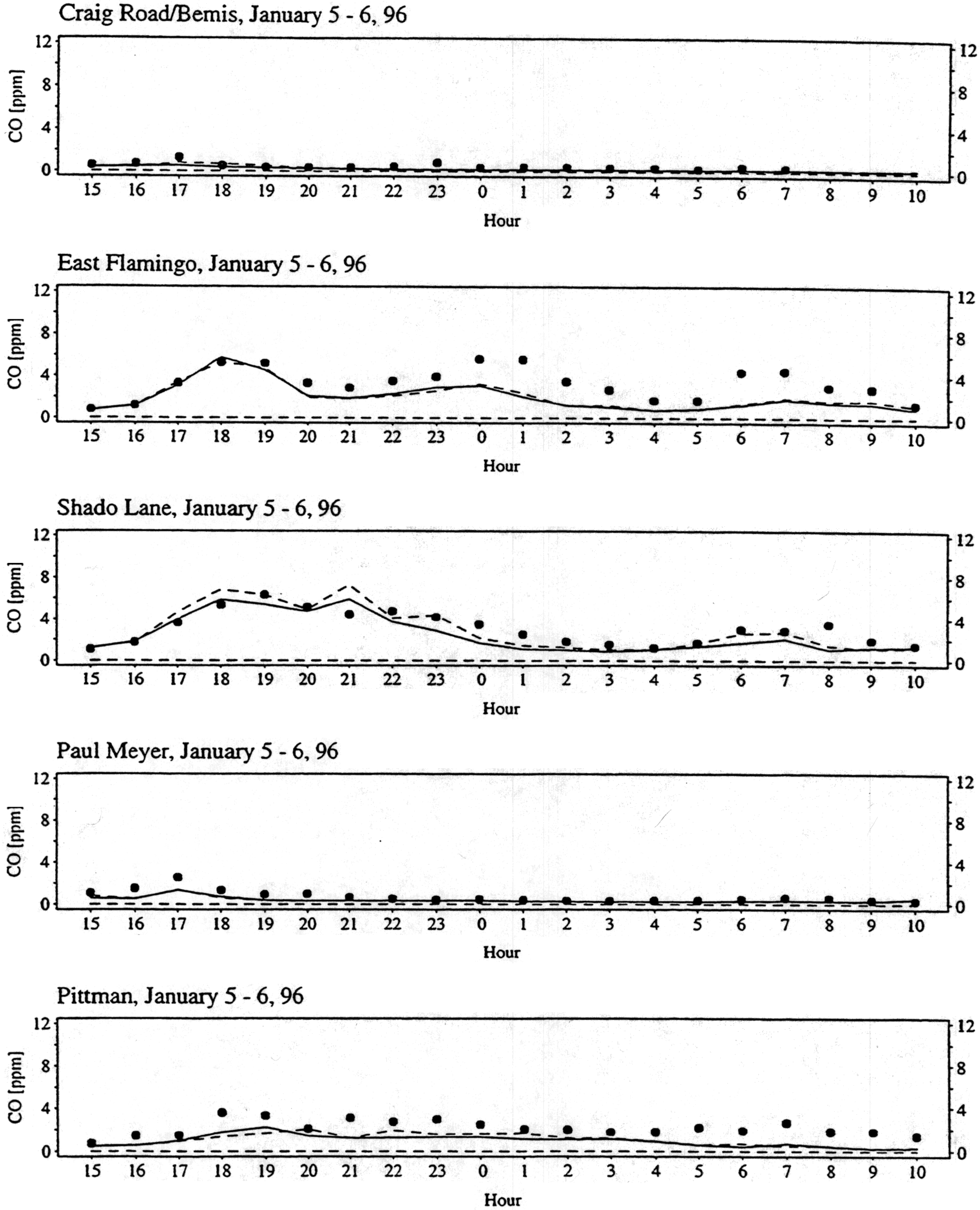

Figure 18. Continued.

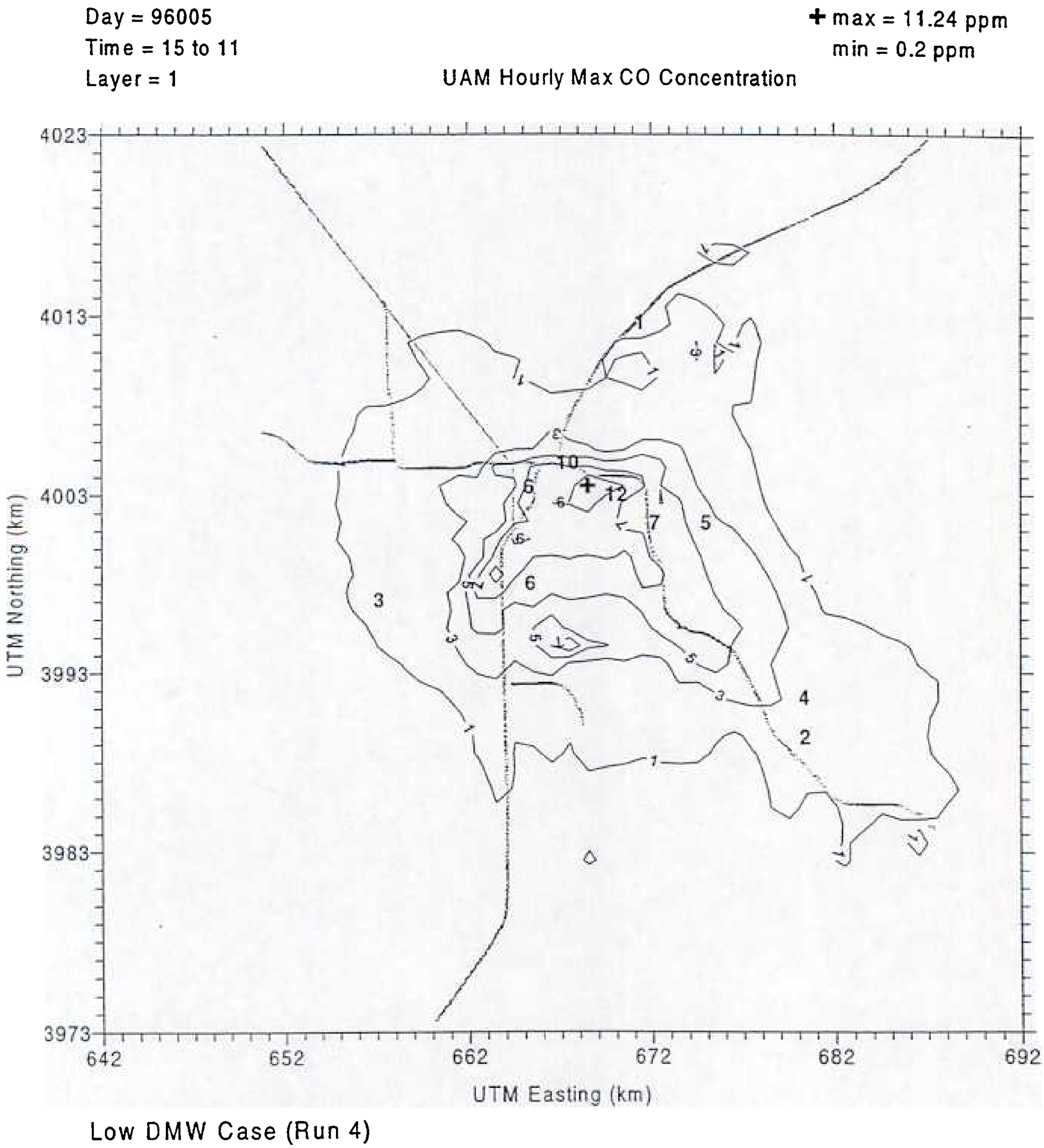

Figure 19. The spatial distribution of UAM predicted hourly maximum CO (ppm) in the Light Mean Wind Case. Contours are given every 1 ppm. Peak hourly observed CO (ppm) are overlaid at locations of APCD monitoring sites.

LVCO Base Case (Run 2) and Low DMW Case (Run 4)

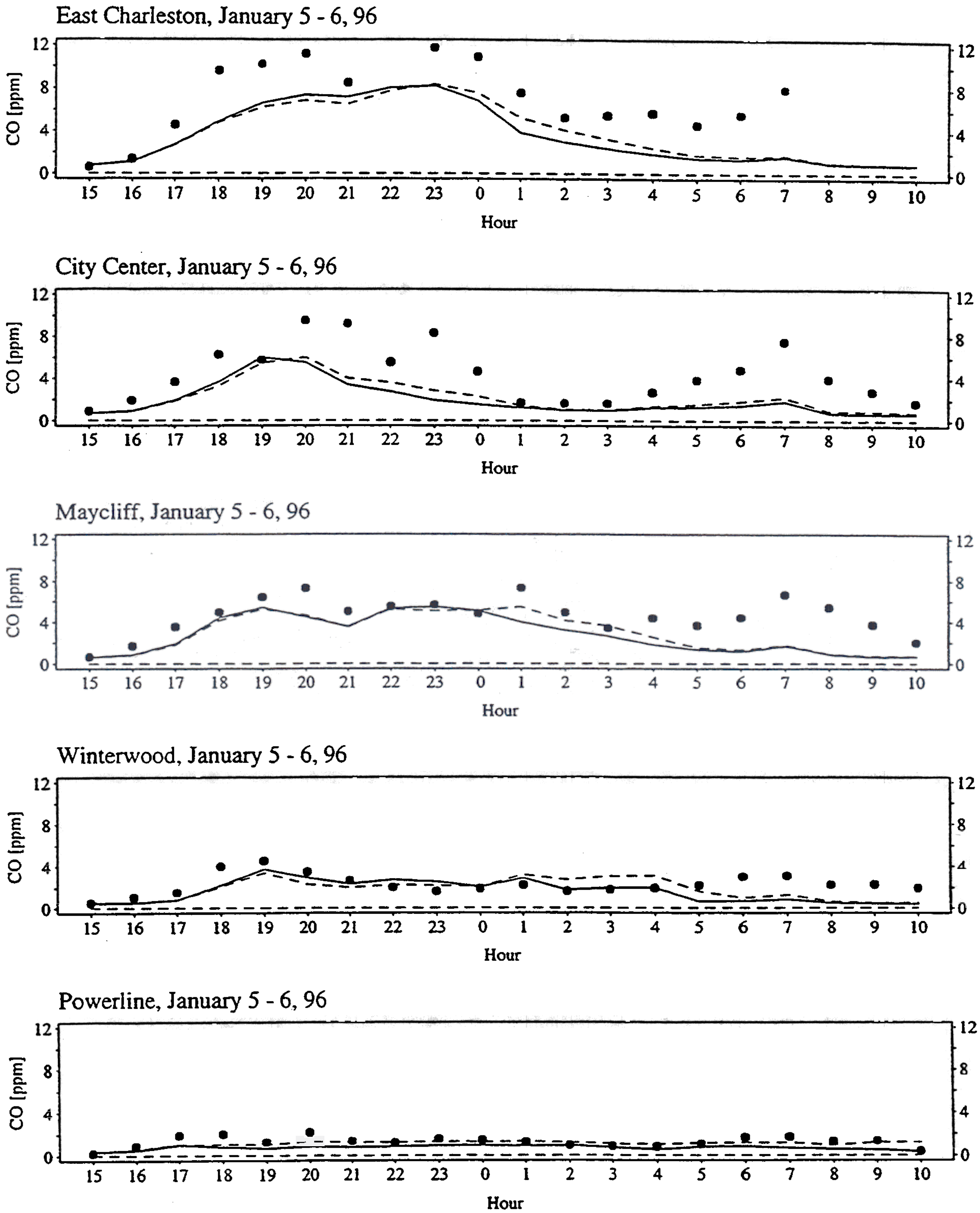

Figure 20. Time series plots comparing UAM predicted hourly CO (ppm) in the Base Case (solid line) and in the Light Mean Wind Case (dashed line). Hourly observations at APCD monitoring sites are indicated by the heavy dots.

LVCO Base Case (Run 2) and Low DMW Case (Run 4)

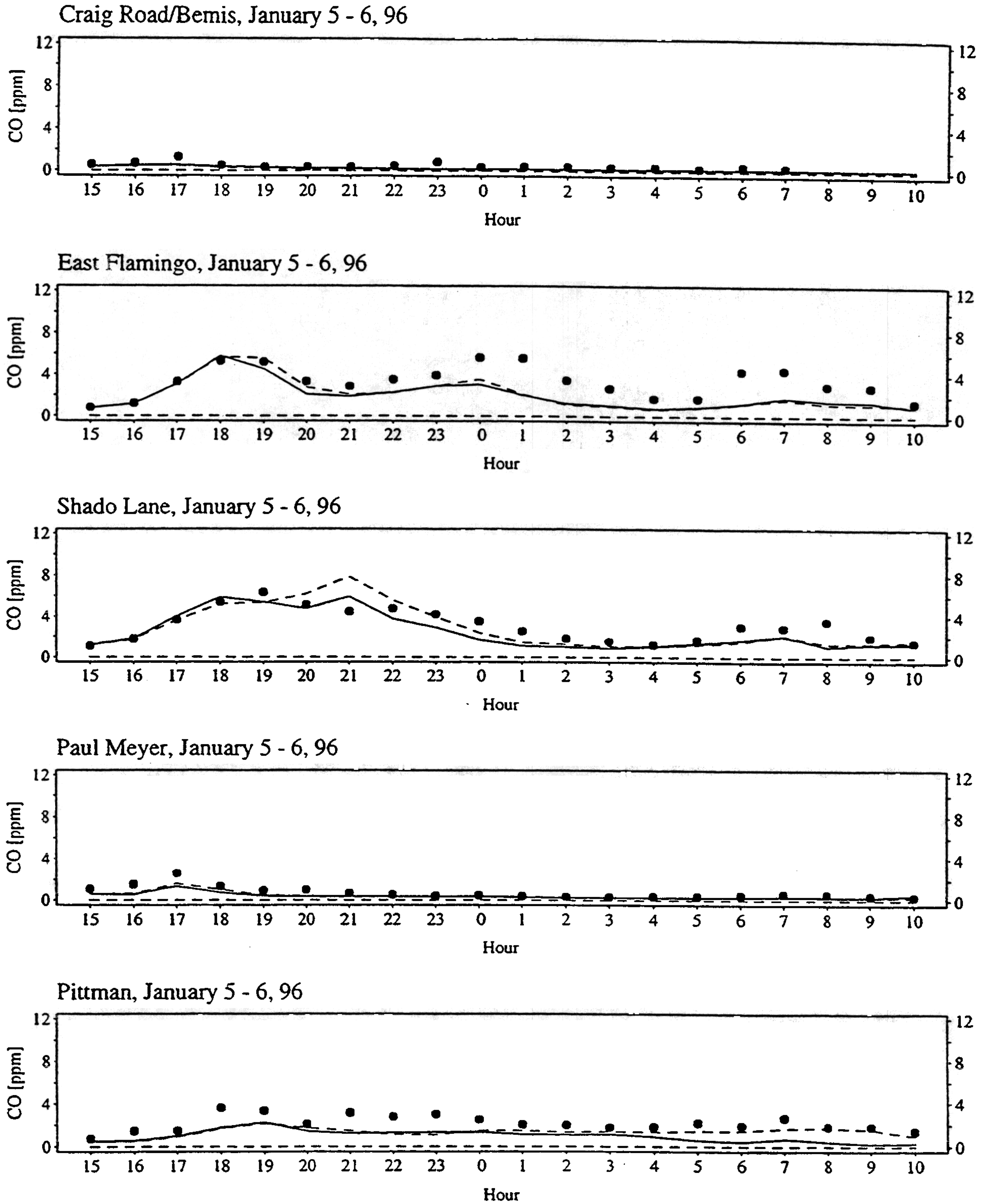

Figure 20. Continued.

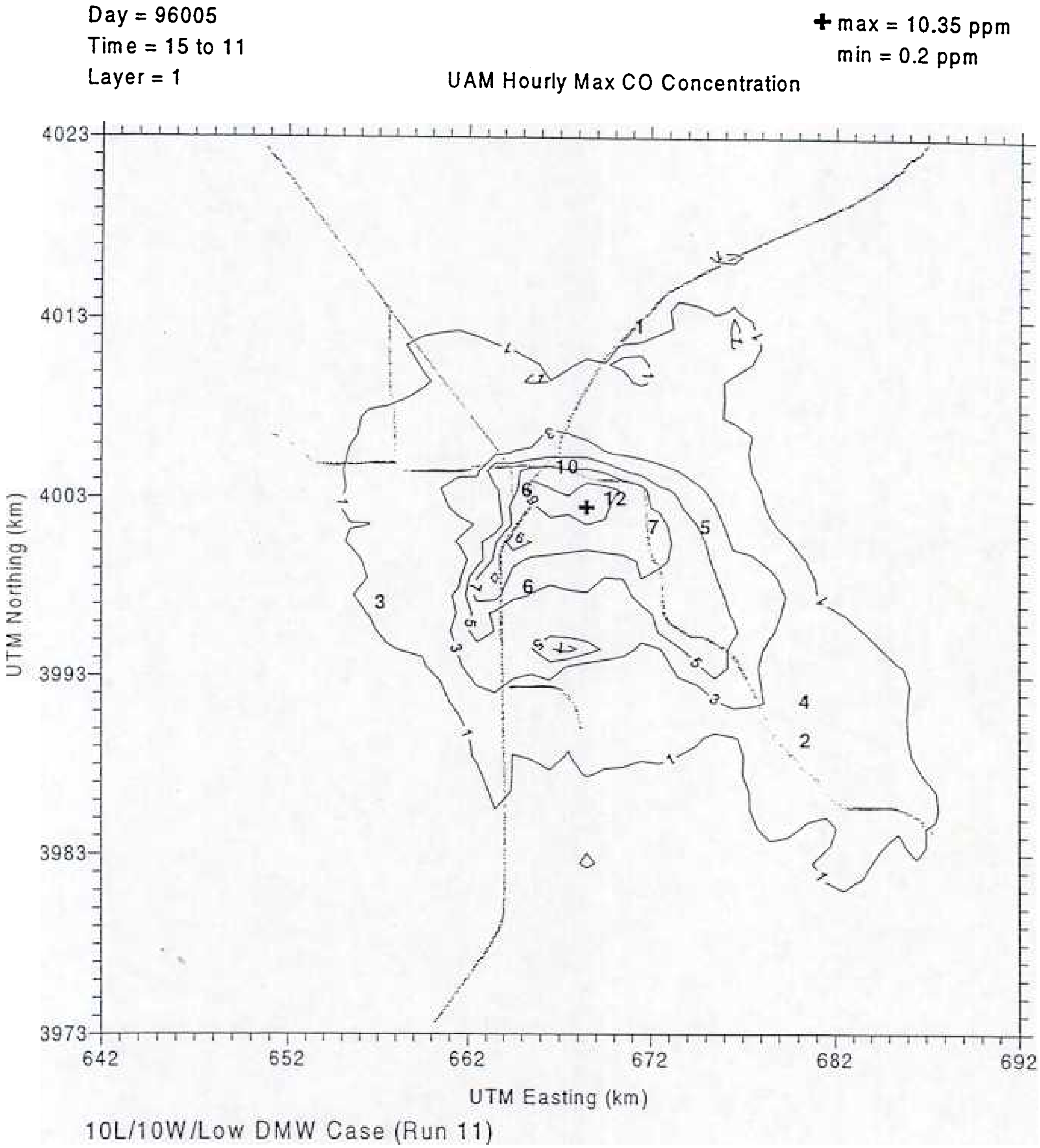

Figure 21. The spatial distribution of UAM predicted hourly maximum CO (ppm) in the Combined Case. Contours are given every 1 ppm. Peak hourly observed CO (ppm) are overlaid at locations of APCD monitoring sites.

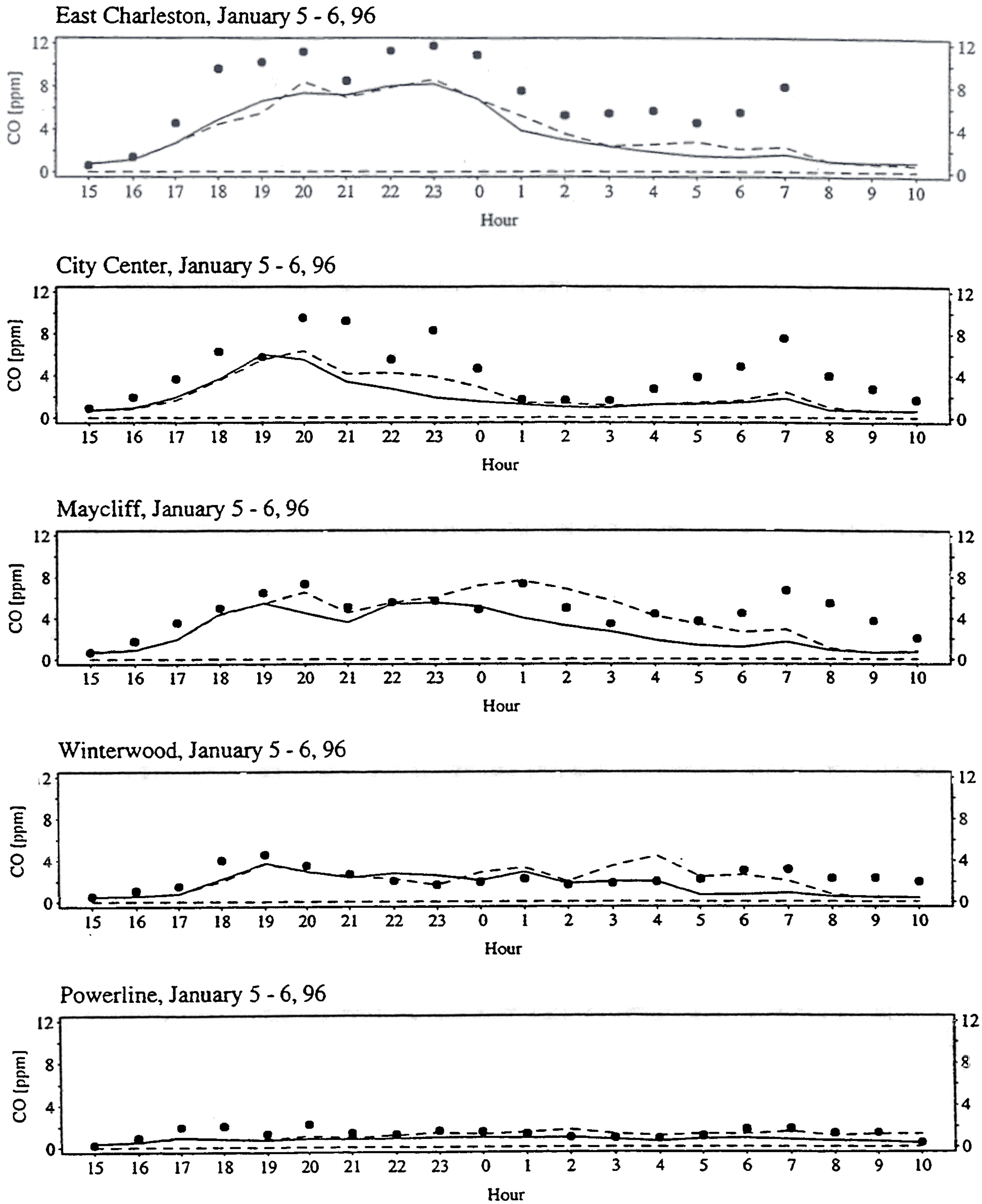

Figure 22. Time series plots comparing UAM predicted hourly CO (ppm) in the Base Case (solid line) and in the Combined Case (dashed line). Hourly observations at APCD monitoring sites are indicated by the heavy dots.

LVCO Base Case (Run 2) and 10L/10W/Low Case (Run 11)

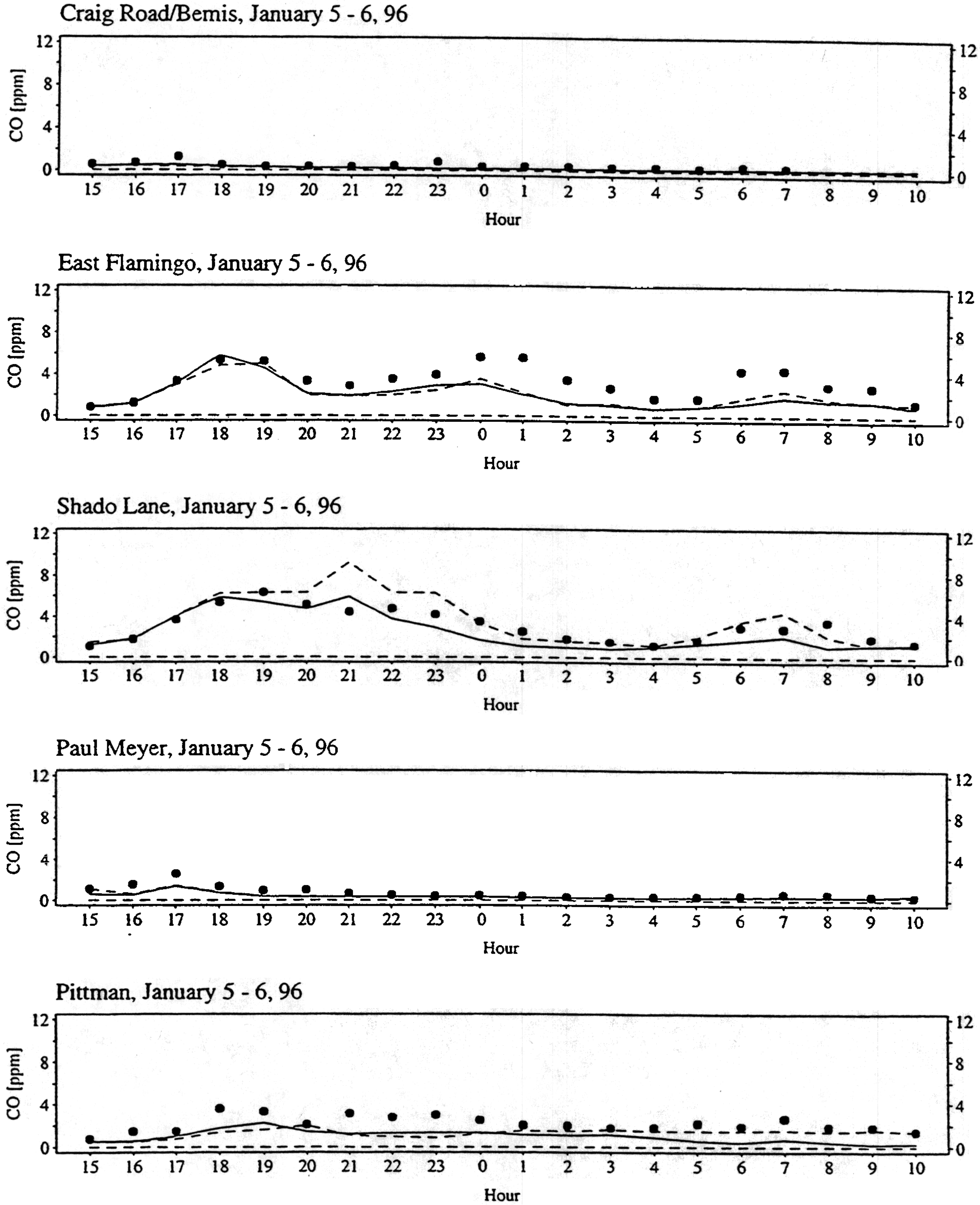

Figure 22. Continued.

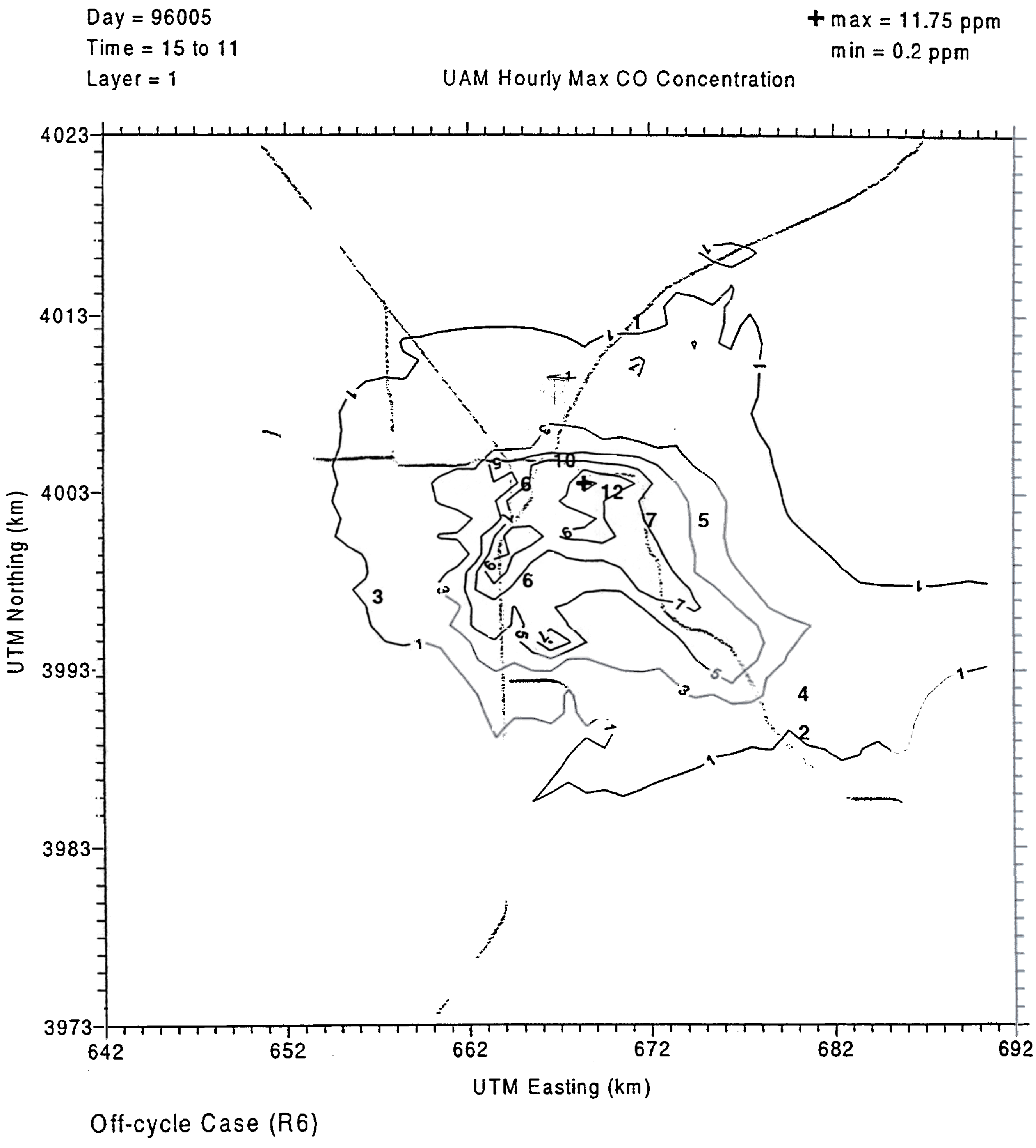

Figure 23. The spatial distribution of UAM predicted hourly maximum CO (ppm) in the Off-cycle Emissions Case. Contours are given every 1 ppm. Peak hourly observed CO (ppm) are overlaid at locations of APCD monitoring sites.

LVCO Base Case (Run 2) and Off-cycle Case (R6)

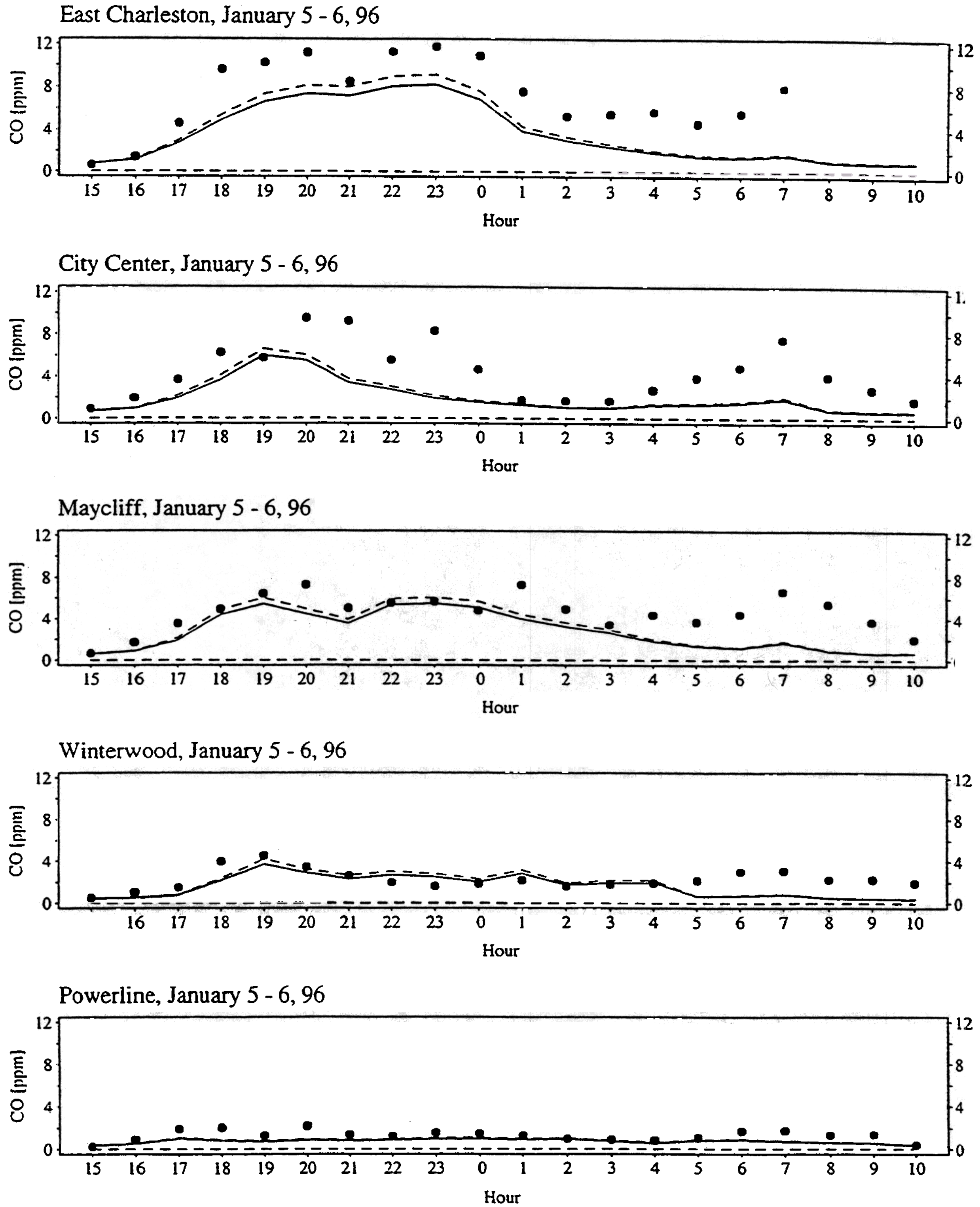

Figure 24. Time series plots comparing UAM predicted hourly CO (ppm) in the Base Case (solid line) and in the Off-cycle Emissions Case (dashed line). Hourly observations at APCD monitoring sites are indicated by the heavy dots.

LVCO Base Case (Run 2) and Off-cycle Case (R6)

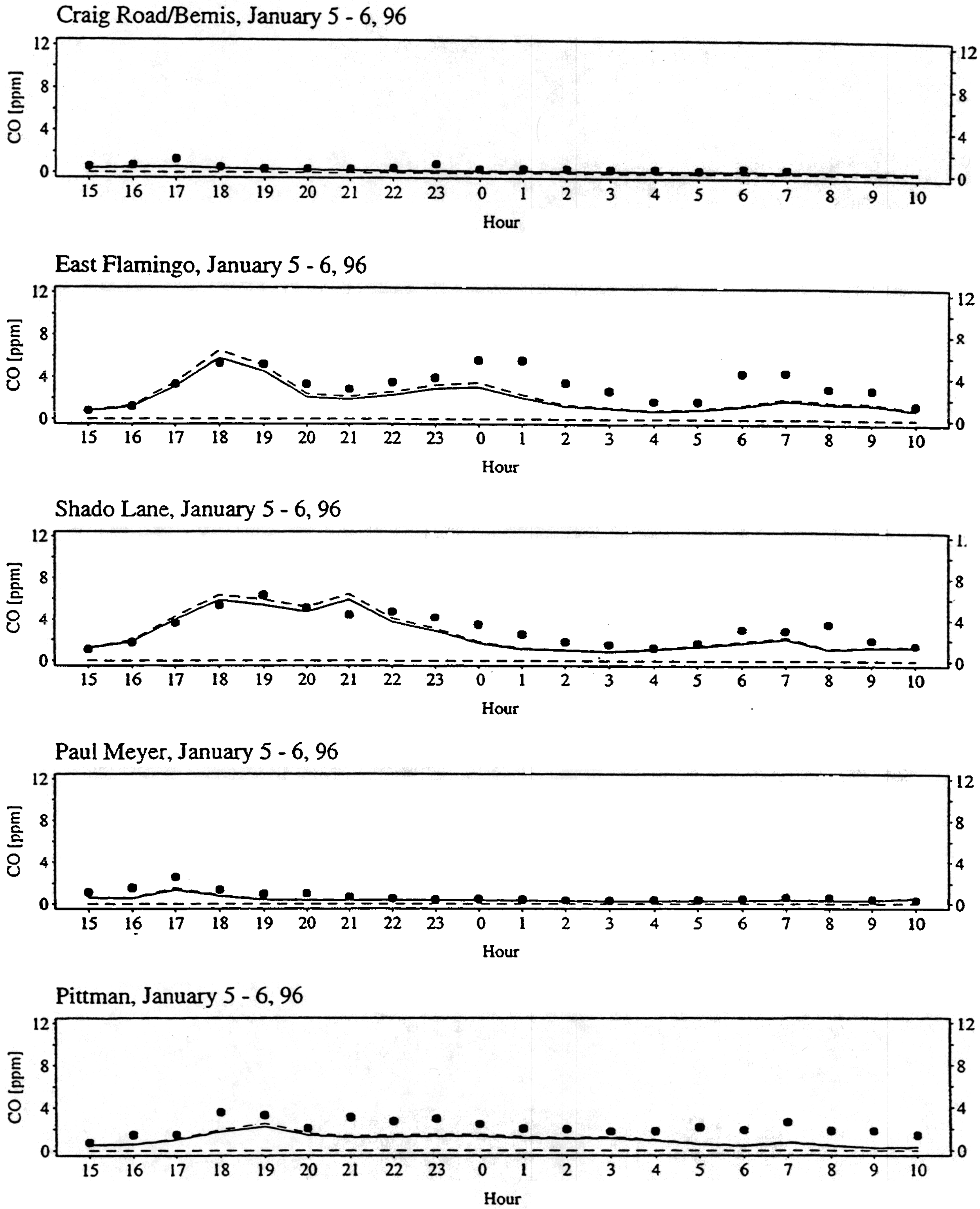

Figure 24. Continued.

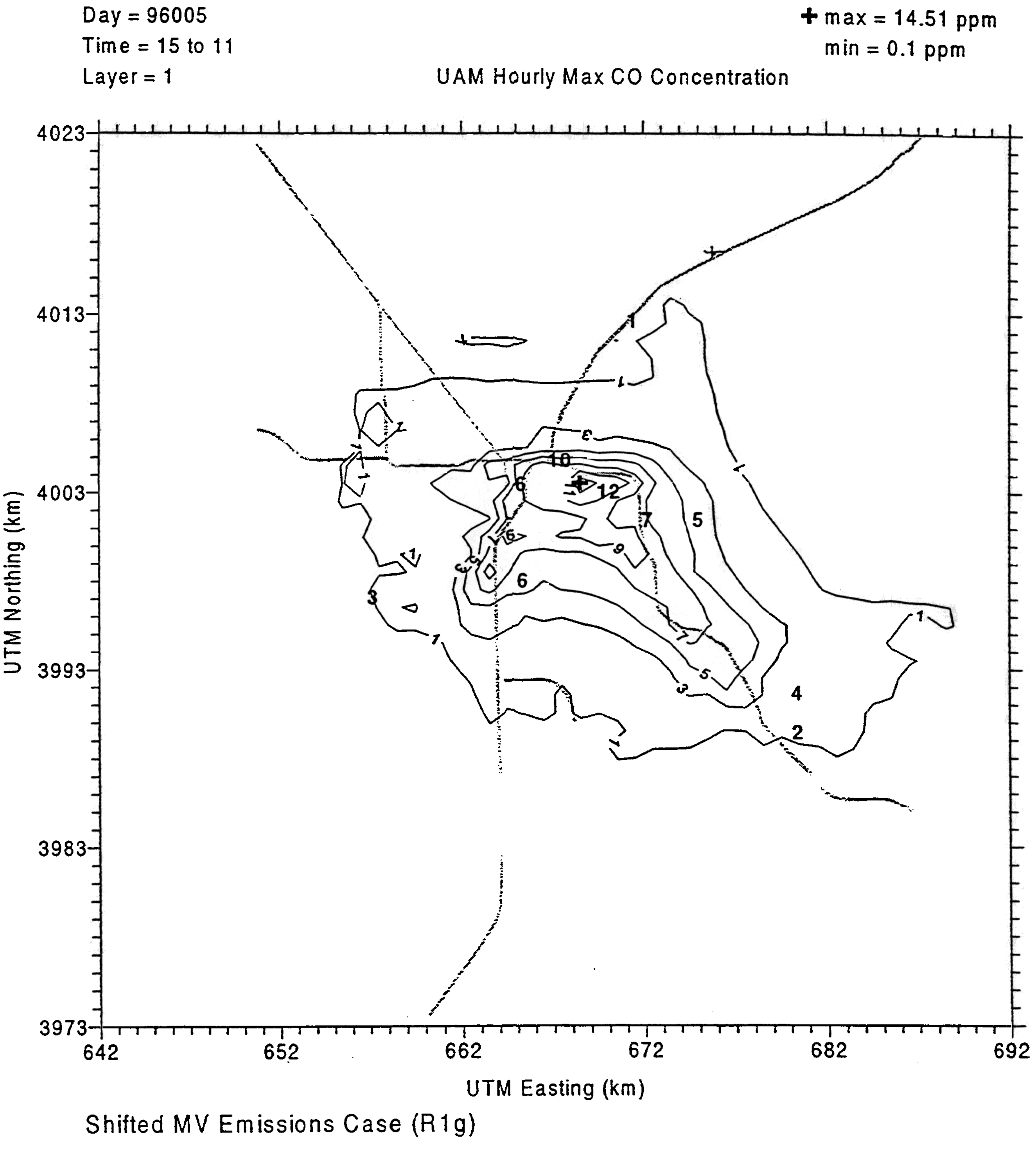

Figure 25. The spatial distribution of UAM predicted hourly maximum CO (ppm) in the Time Shifted Emissions Case. Contours are given every 1 ppm. Peak hourly observed CO (ppm) are overlaid at locations of APCD monitoring sites.

LVCO Base Case (Run 2) and Shifted MV Emissions (R1g)

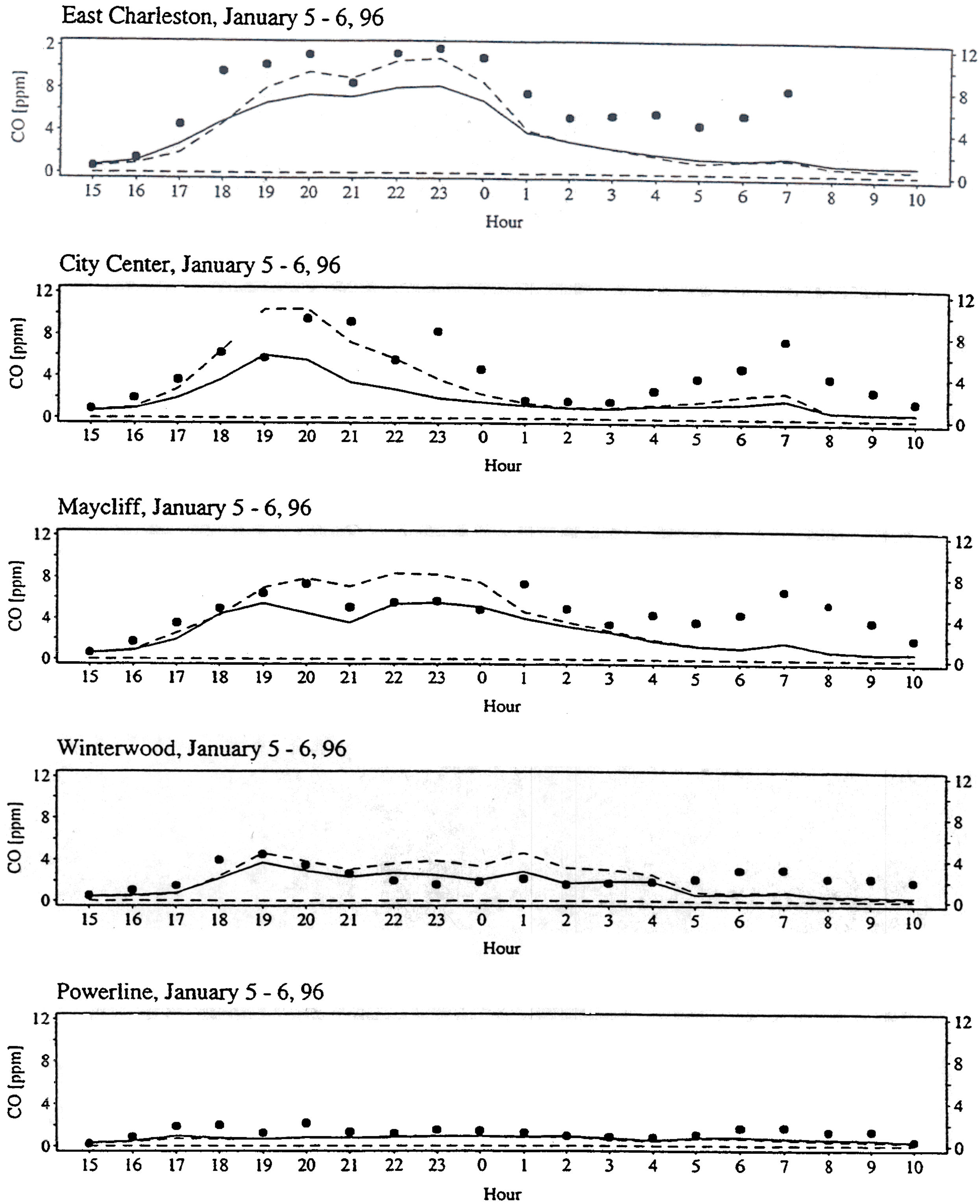

Figure 26. Time series plots comparing UAM predicted hourly CO (ppm) in the Base Case (solid line) and in the Time Shifted Emissions Case (dashed line). Hourly observations at APCD monitoring sites are indicated by the heavy dots.

LVCO Base Case (Run 2) and Shifted MV Emissions (R1g)

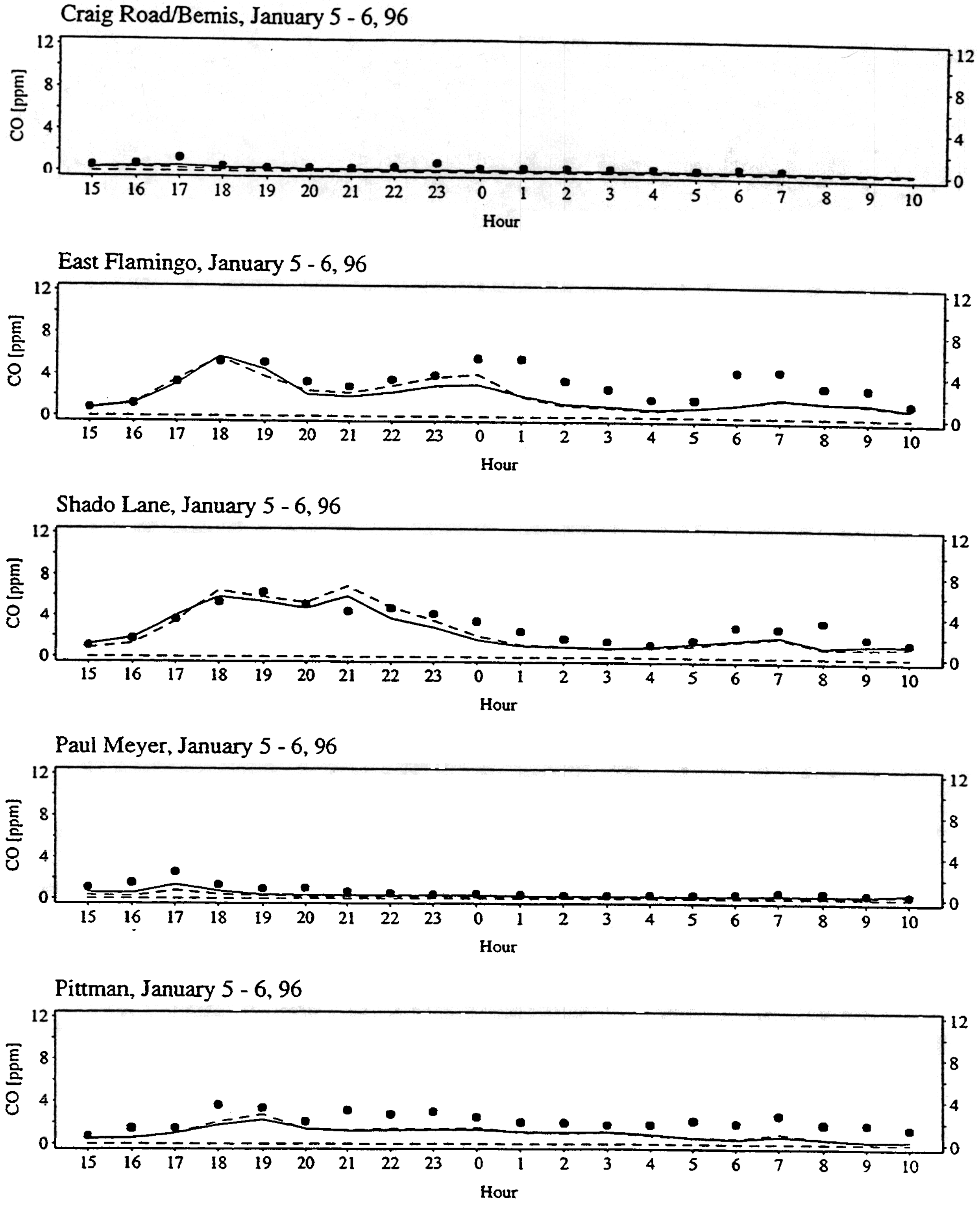

Figure 26. Continued.

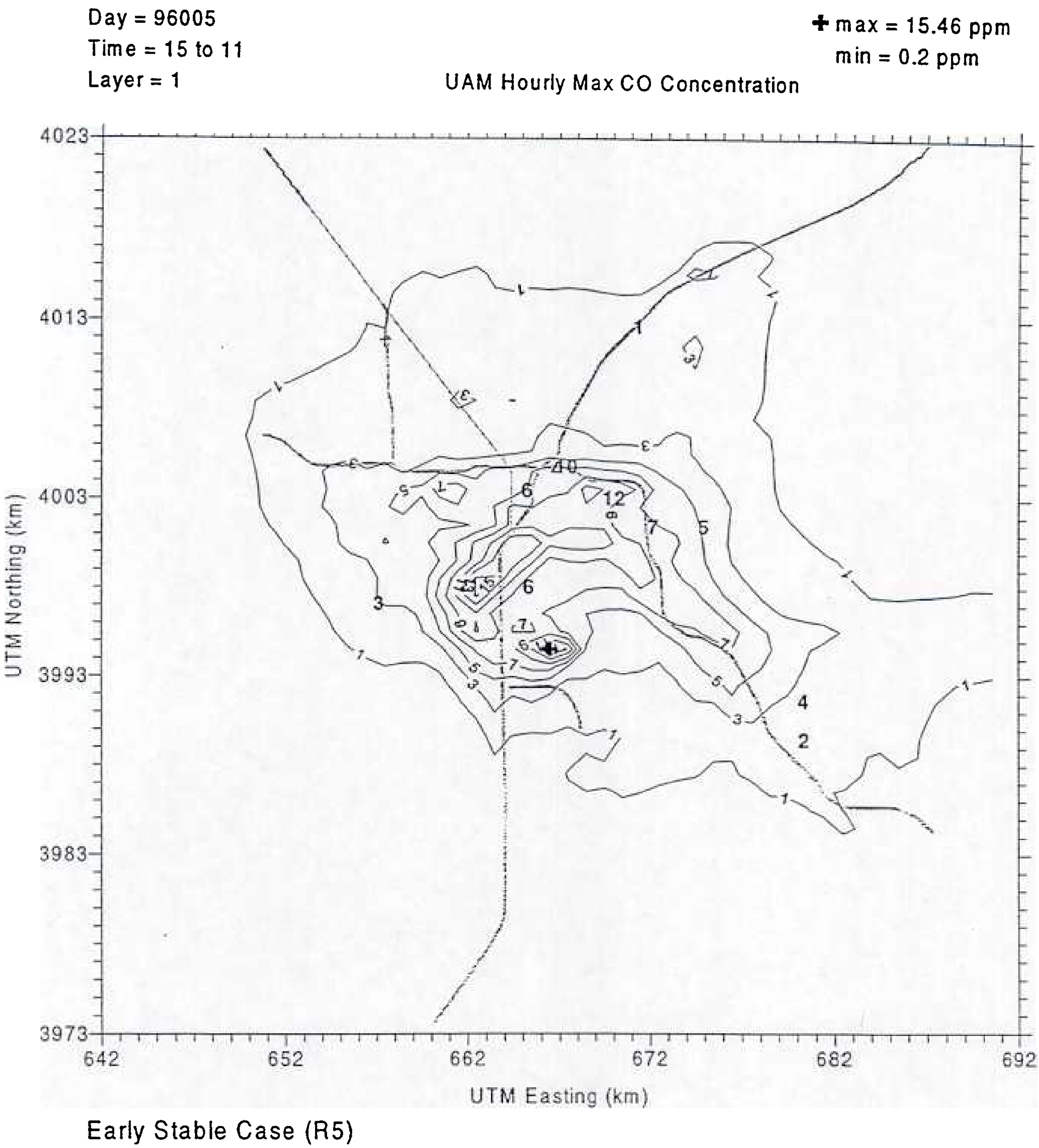

Figure 27. The spatial distribution of UAM predicted hourly maximum CO (ppm) in the Early Stabilization Case. Contours are given every 1 ppm. Peak hourly observed CO (ppm) are overlaid at locations of APCD monitoring sites.

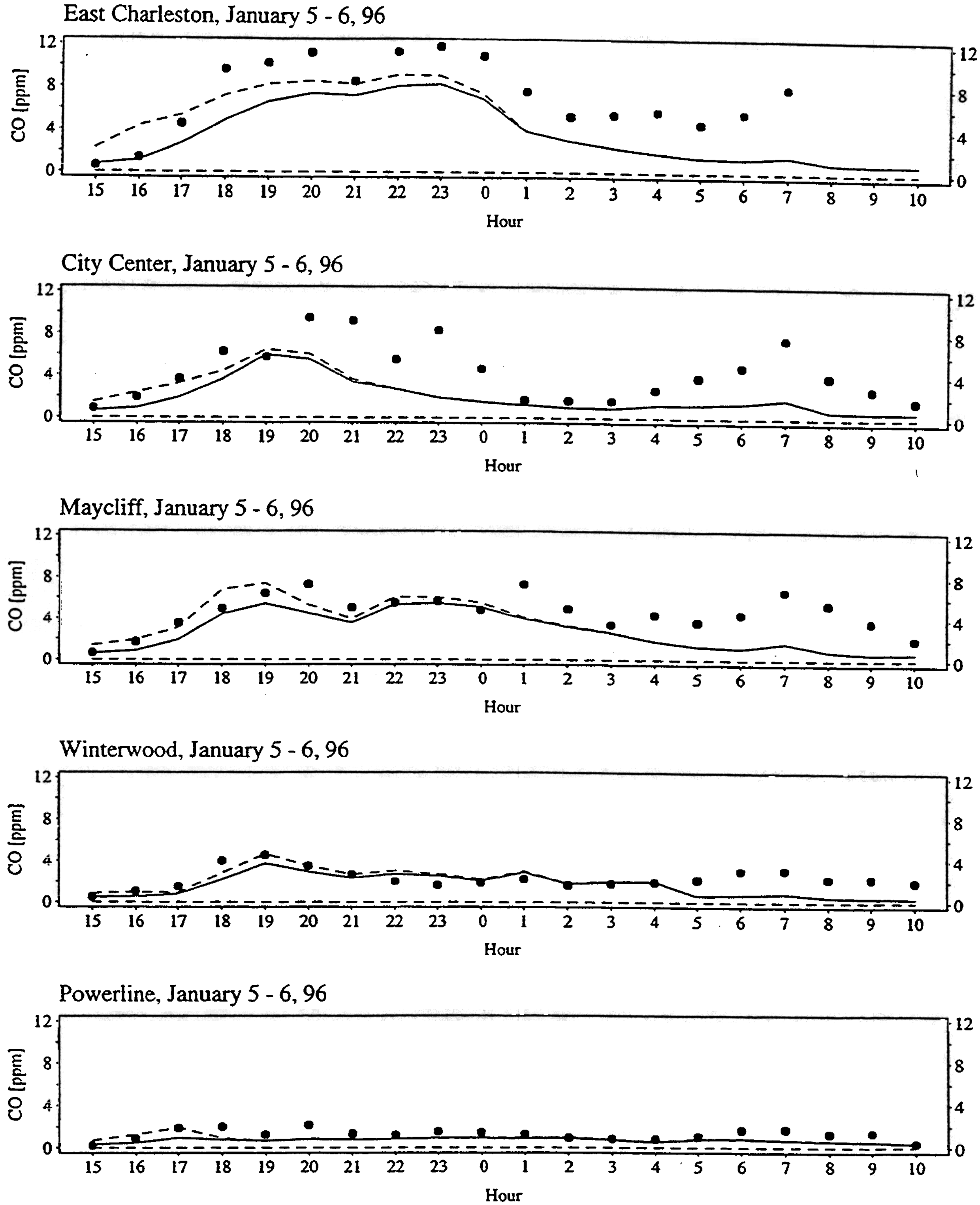

Figure 28. Time series plots comparing UAM predicted hourly CO (ppm) in the Base Case (solid line) and in the Early Stabilization Case (dashed line). Hourly observations at APCD monitoring sites are indicated by the heavy dots.

LVCO Base Case (Run 2) and Early Stable Case (R5)

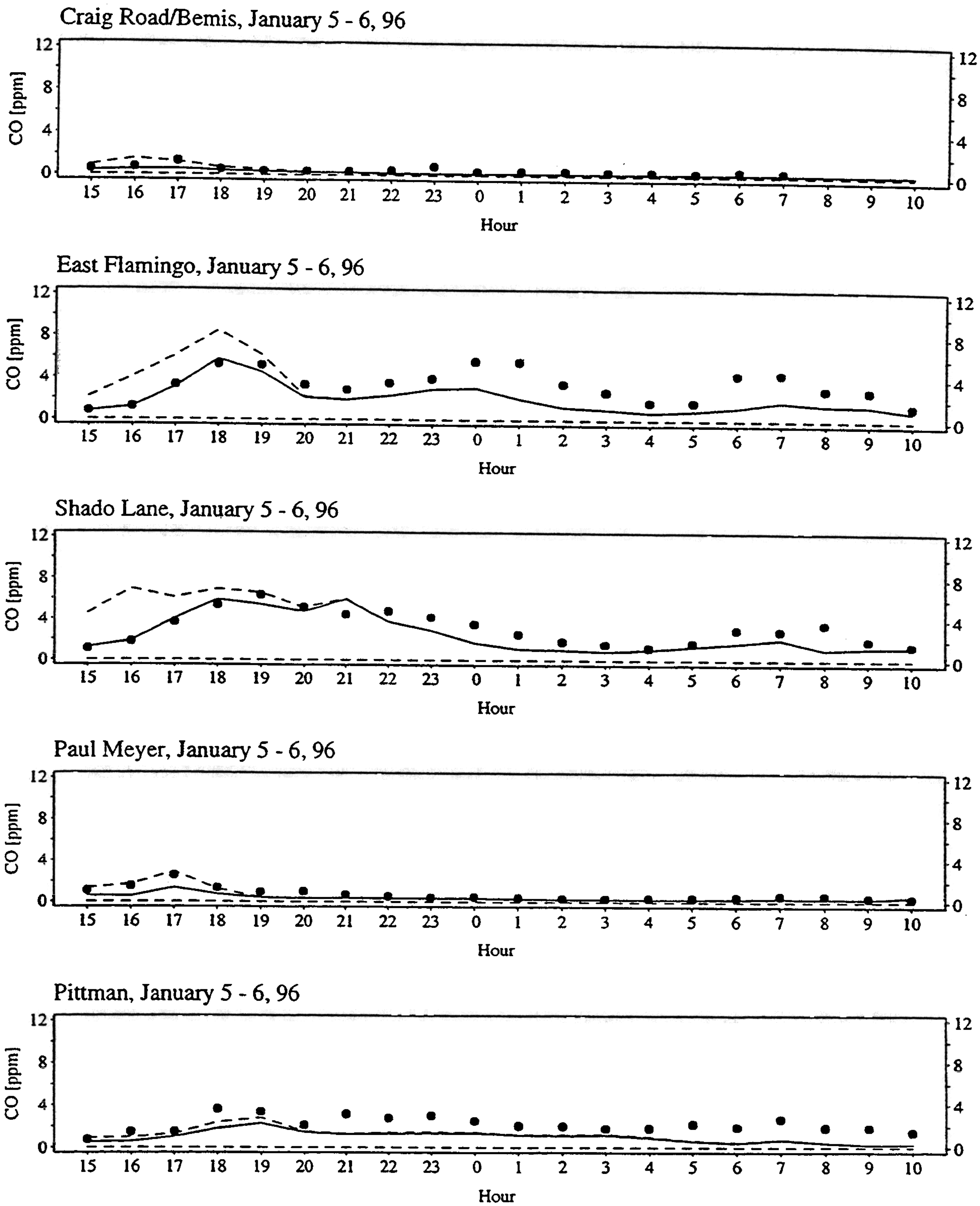

Figure 28. Continued.

APPENDIX B

EXAMPLE OF A SOURCE APPORTIONMENT APPLICATION WITH THE UAM OZONE TOOL

EXAMPLE OF A SOURCE APPORTIONMENT APPLICATION WITH THE UAM OZONE TOOL

The basis of current thinking on control strategies and future year maintenance of CO NAAQS in Clark County rests on the idea of defining sub-regional emission budgets for the LVV. The idea is based upon the fact that a few localized heavy emission areas are seen (both via monitoring and modeling) to contribute a majority of CO in problem areas in valley. It is not reasonable to place a control burden on the entire valley by specifying a single basin-wide CO budget, since the vast majority of valley area is not contributing to these small problem areas. It is much more reasonable to control certain key source areas, such as providing for local traffic improvements. This allows for separate emission budgets to be defined for outer areas, which in turn would allow further growth without endangering conformity of the CO NAAQS.

Modeling is key to defining appropriate sub-regional emission budgets. The problem is that the modeling must be sufficiently robust to ensure that key sources and subsequent dispersion are depicted correctly. We see the use of model "tracers" as the major tool in the process of developing emission budgets. The UAM has been modified to track photochemical precursors to apportion ozone air quality to various sources by geographic region and/or source type. This model is known as the Ozone Tool, and was developed for the South Coast Air Quality Management District in California (Yarwood et al., 1996). It is fairly straightforward to utilize this model for inert CO. While modeling CO with UAM is quick, and several runs for each sub-area could be performed separately to obtain the same information, the Ozone Tool allows this process to be performed in just one run, by simply supplying the model with a source area map defined by regions of grid cells. In this way, any number of source regions, even down to each model individual grid cell, could be treated without developing separate emission files for each individual source area. Of coarse, caution should be taken in over-defining source regions, since the accuracy of emissions in a given region tends to deteriorate as the region size approaches a single cell on the order of 1 km.

This appendix presents an example exercise with the UAM Ozone Tool, in which 8 source areas were defined, and CO emissions from each area were tracked and tallied for each grid cell to develop an example source-area budget for peak CO in the traditional problem area (East Charleston and Sunrise Acres). Emissions from each region were stratified into two separate source categories as well: mobile sources, and all remaining sources. In this example, the Ozone Tool provides an interesting diagnostic illustration into UAM performance at key sites. For example, our source area configuration allows for an analysis on how the modeled CO maxima produced around the northern Las Vegas Boulevard Strip affect total CO reaching East Charleston and other sites.

Figure B-1 provides an illustration of how the UAM domain was divided into eight general source regions. Four large outlying areas occupy the four corners of the domain, with a typical size that exceeds 20×20 km^2. Three inner areas were defined for central Las Vegas: the northern Las Vegas Boulevard Strip, to track the large emission source in that area; northeastern Las Vegas, to track emissions related to U.S. 95; and southeastern Las Vegas. A final (leftover) region extends eastward from U.S. 95 toward Lake Mead. The Ozone Tool automatically tracks contributions from initial and boundary conditions as well. The model offers the option to further break down contributions from the individual four boundaries, or report the total from all boundaries; in this example, only the total boundary contributions are reported.

As mentioned above, emissions were stratified into mobile and all remaining sources. The Ozone Tool requires a separate emissions file for each specific stratification, so in this example the UAM-ready mobile source component emissions file was supplied along with the standard total UAM ready emissions file (the Ozone Tool takes the difference of these two to obtain the remaining fraction). The model produces the standard UAM output concentration file, as well as a tracer file in the same UAM output format. A postprocessor reads this file and produces an Excel spreadsheet that can be used to further analyze the data and produce graphical displays.

The Ozone Tool was run for both Phase II episodes for the source regions shown in Figure B-1. The daily maximum CO distributions from each region in the December 19-20 episode are shown as contour plots in Figures B-2 through B-9. Note that while the larger corner regions emit large fractions of the total CO in the basin, they produce small localized contributions because they have generally low emission densities. The higher emission densities associated with the inner regions show that these areas contribute the majority of CO impacting downtown Las Vegas and the East Charleston area.

Figures B-10 through B-14 display time series plots of predicted CO contributions at selected monitoring sites for the same episode. The contribution from mobile sources in all eight regions, the total of all remaining emissions, initial conditions, and boundary conditions are plotted in a cumulative fashion, so that both the relative contributions from each and the total predicted CO are displayed (these types of plots are commonly referred to as “landscape” plots). These plots show the dominance of the inner regions in contributing to high CO at each receptor. Another large contributor is Region 2 (the northwest corner of the domain), which includes the I-15/U.S. 95 highway interchange in its southeast corner. From Figure B-3, it is evident that high CO concentrations from Region 2 stem from this interchange, and that the rest of this area contributes much less than 1 ppm. For most of the time series, it is evident that local emissions from the region in which each site resides dominate the high predicted CO. Note, however, that for the Maycliff site (MC), which is downstream of the high emission areas, the inner regions all contribute evenly, which suggests transport rather than local emissions as the dominant cause of high CO in that area. East Charleston (EC) also indicates equivalent contributions from many source areas during the night, but also shows peak morning CO from mainly the host region.

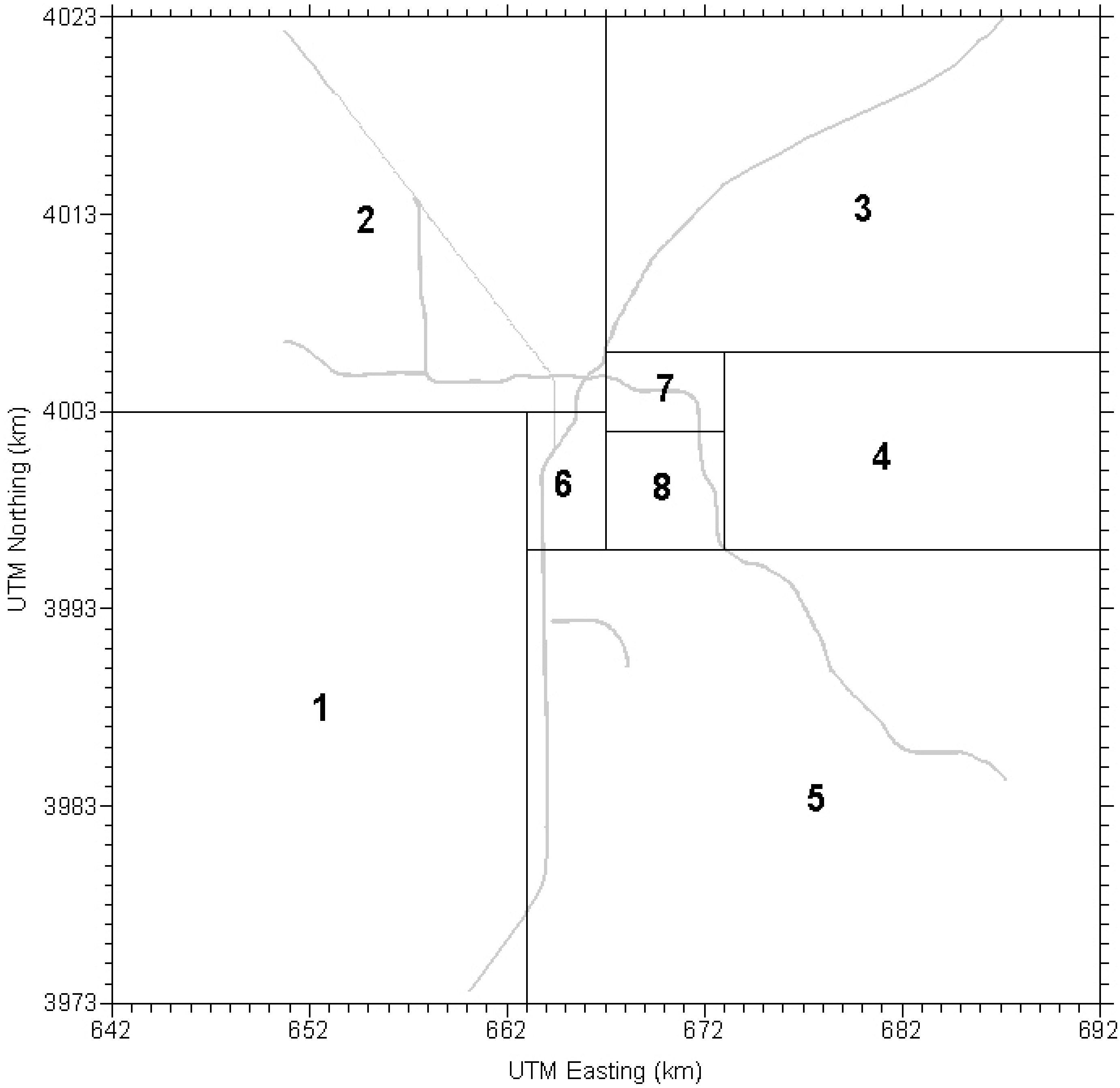

Figure B-1. Breakdown of the entire UAM modeling grid into 8 sub-regional source areas in the Ozone Tool applications.

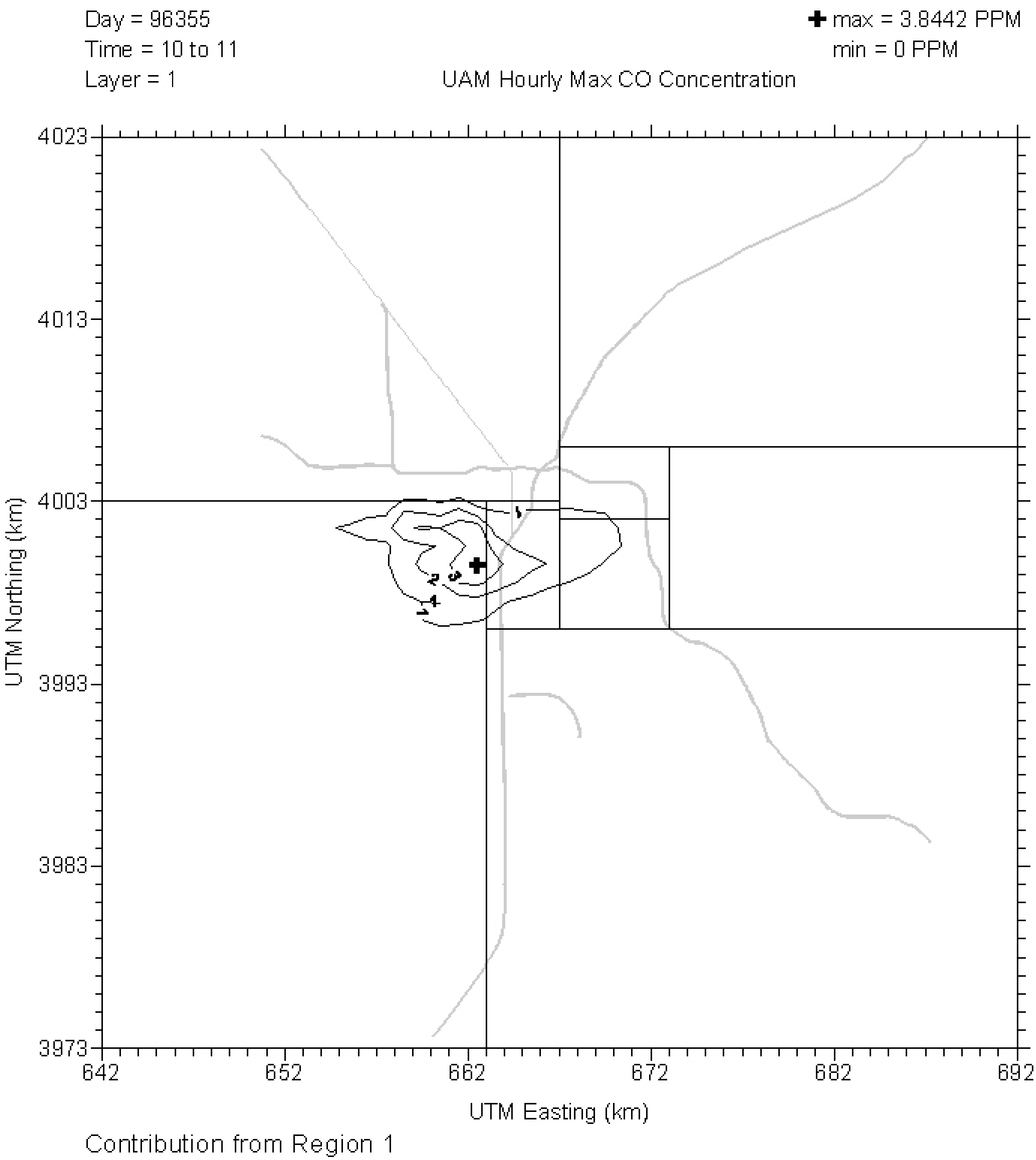

Figure B-2. Contribution of Region 1 to total maximum hourly CO concentration in the December 19-20, 1996 modeling episode.

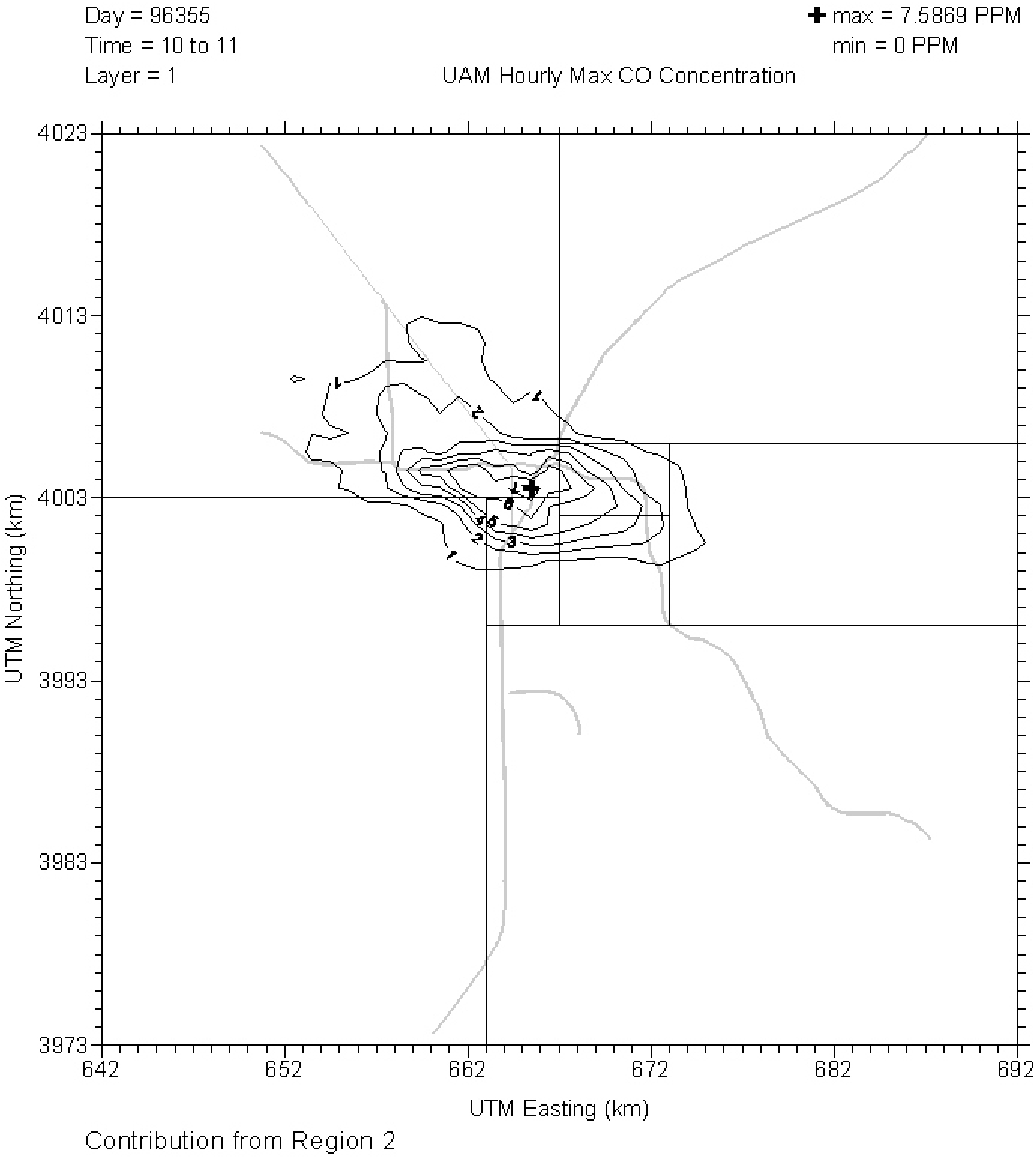

Figure B-3. Contribution of Region 2 to total maximum hourly CO concentration in the December 19-20, 1996 modeling episode.

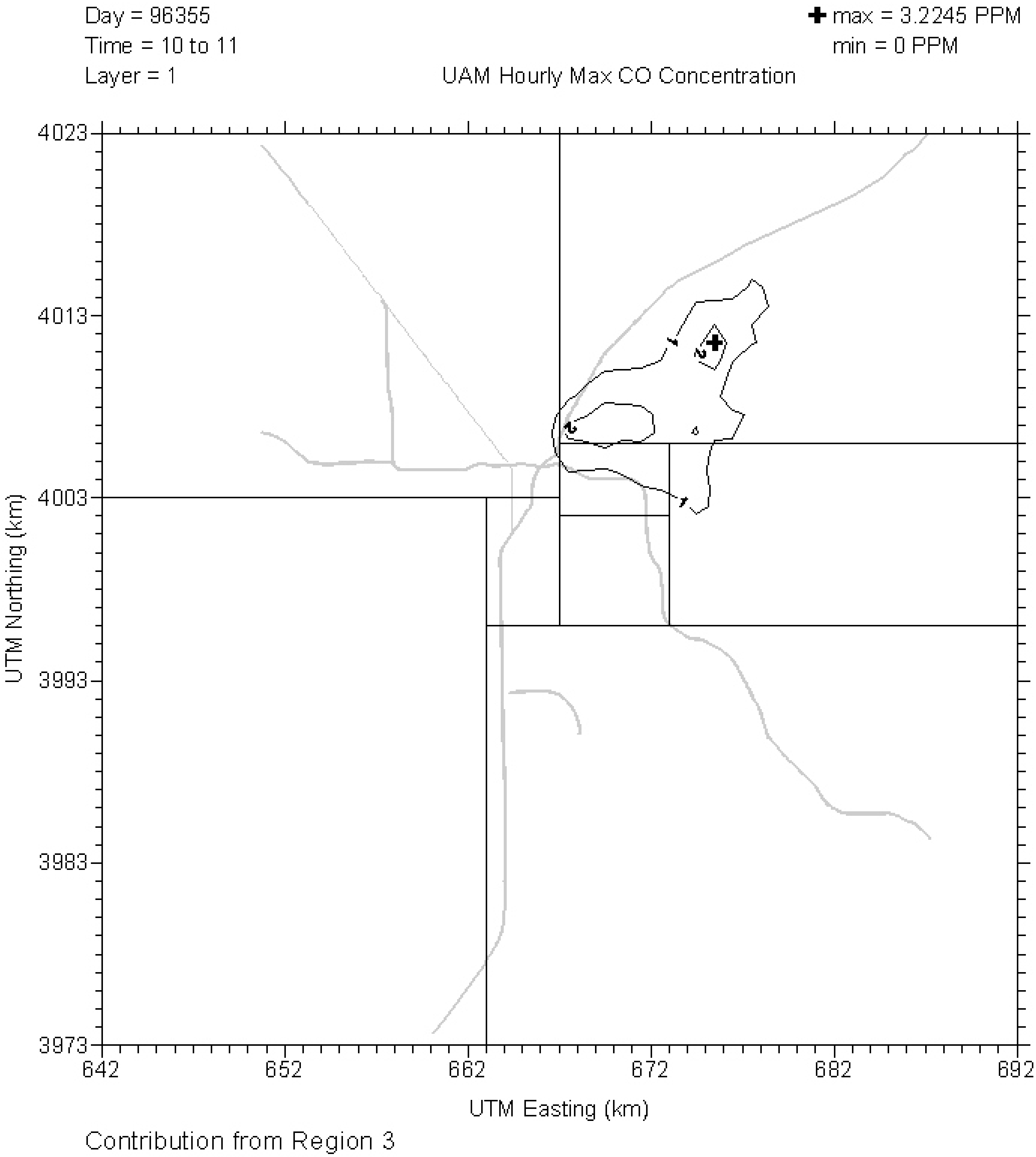

Figure B-4. Contribution of Region 3 to total maximum hourly CO concentration in the December 19-20, 1996 modeling episode.

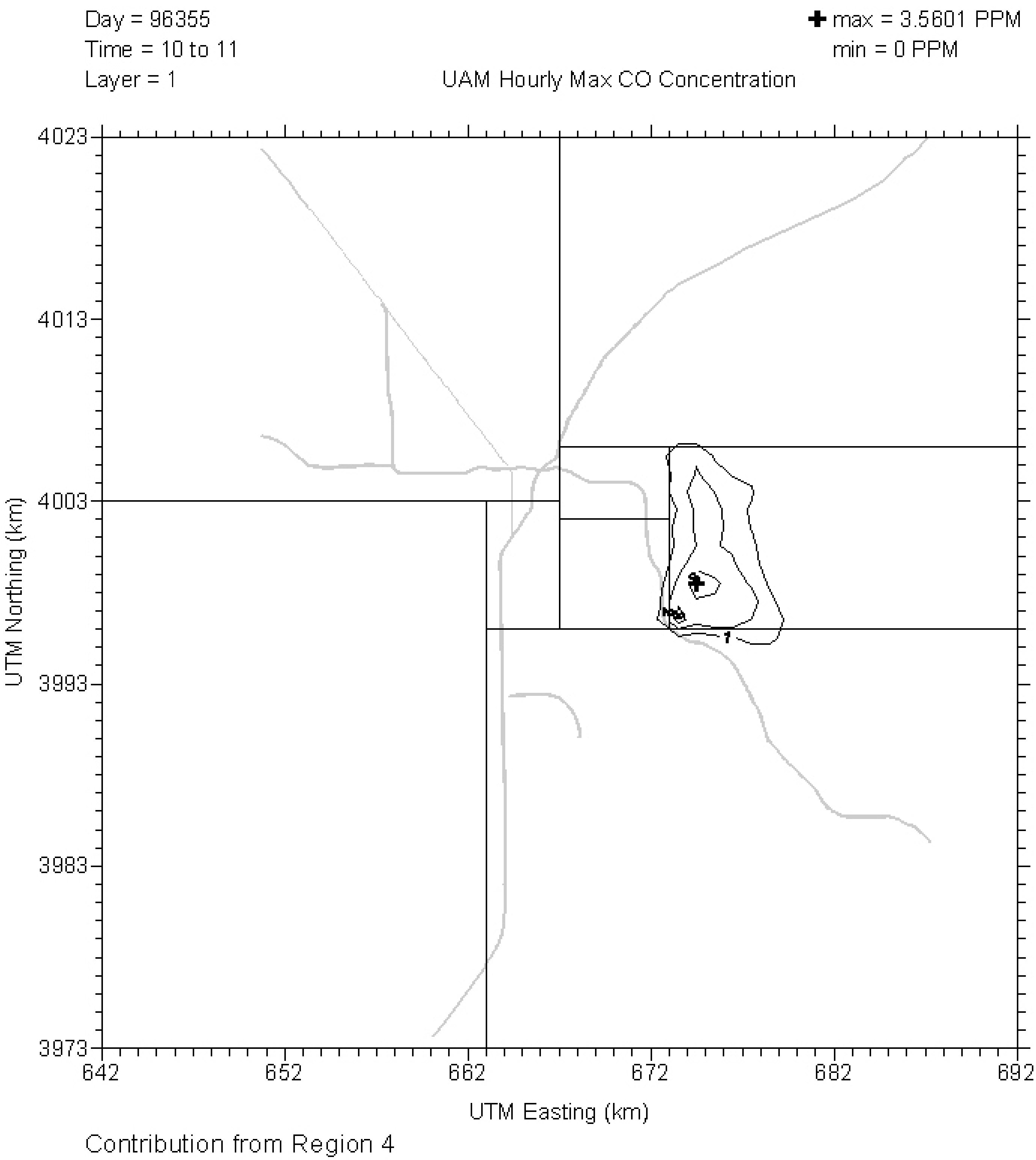

Figure B-5. Contribution of Region 4 to total maximum hourly CO concentration in the December 19-20, 1996 modeling episode.

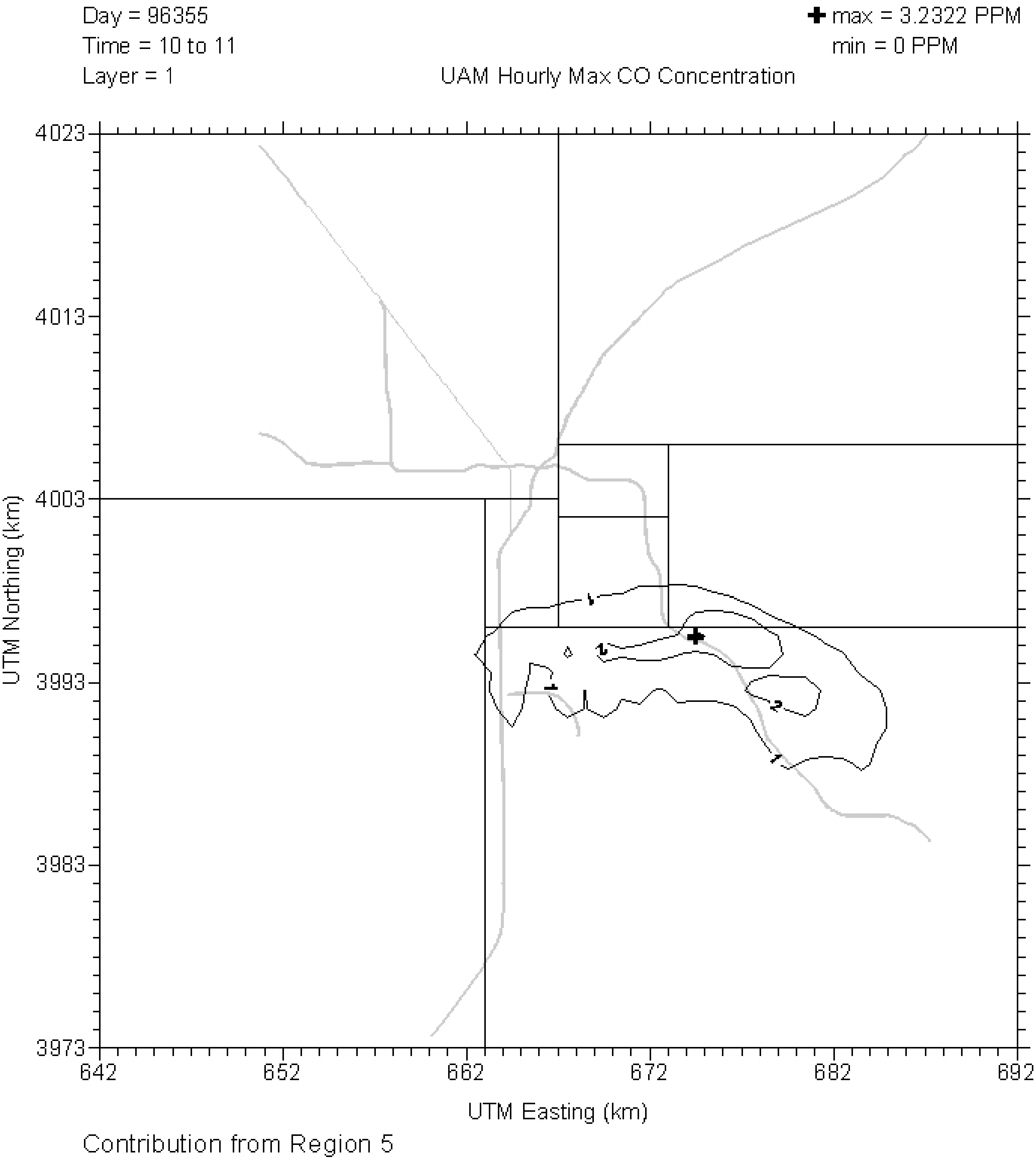

Figure B-6. Contribution of Region 5 to total maximum hourly CO concentration in the December 19-20, 1996 modeling episode.

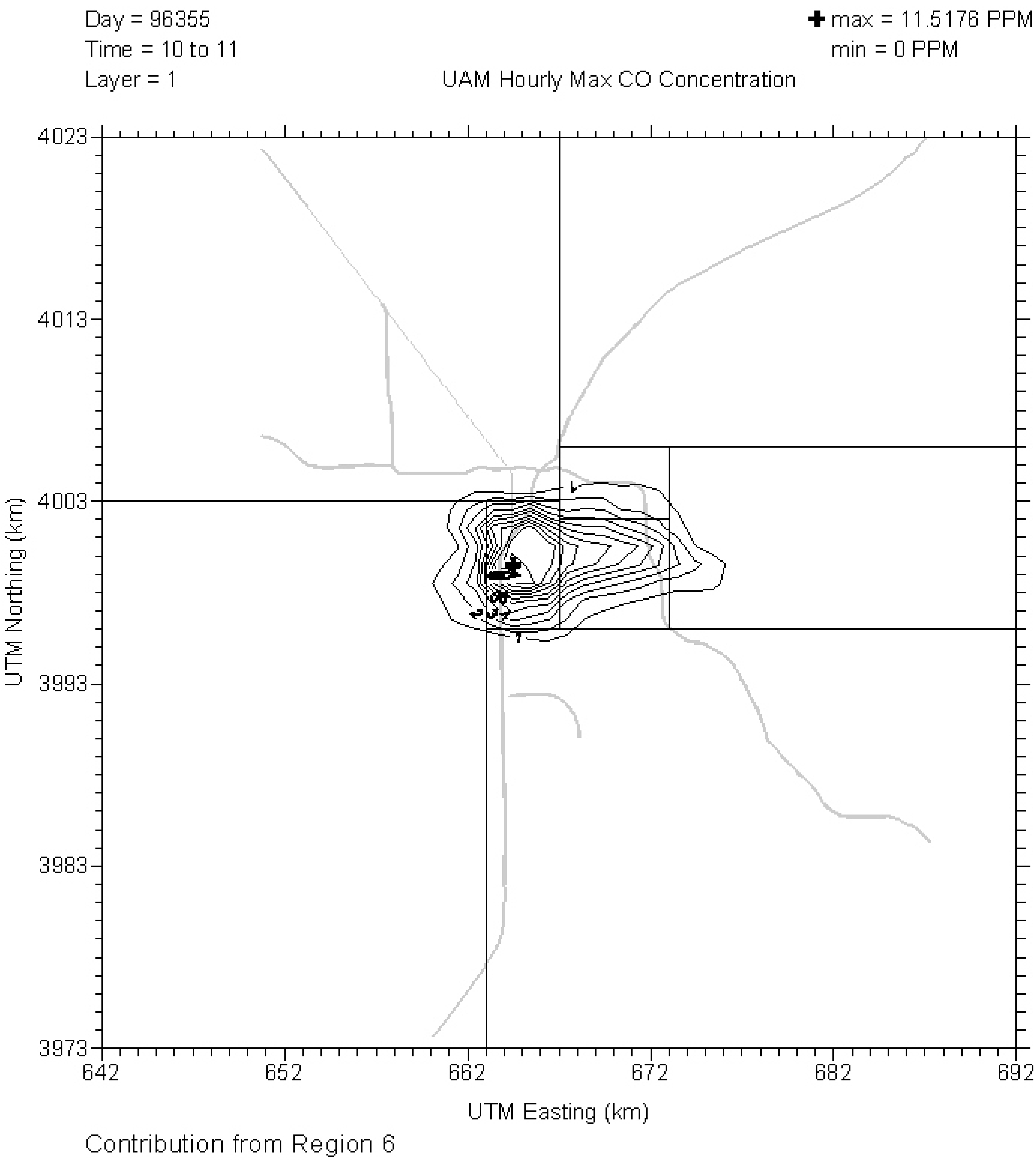

Figure B-7. Contribution of Region 6 to total maximum hourly CO concentration in the December 19-20, 1996 modeling episode.

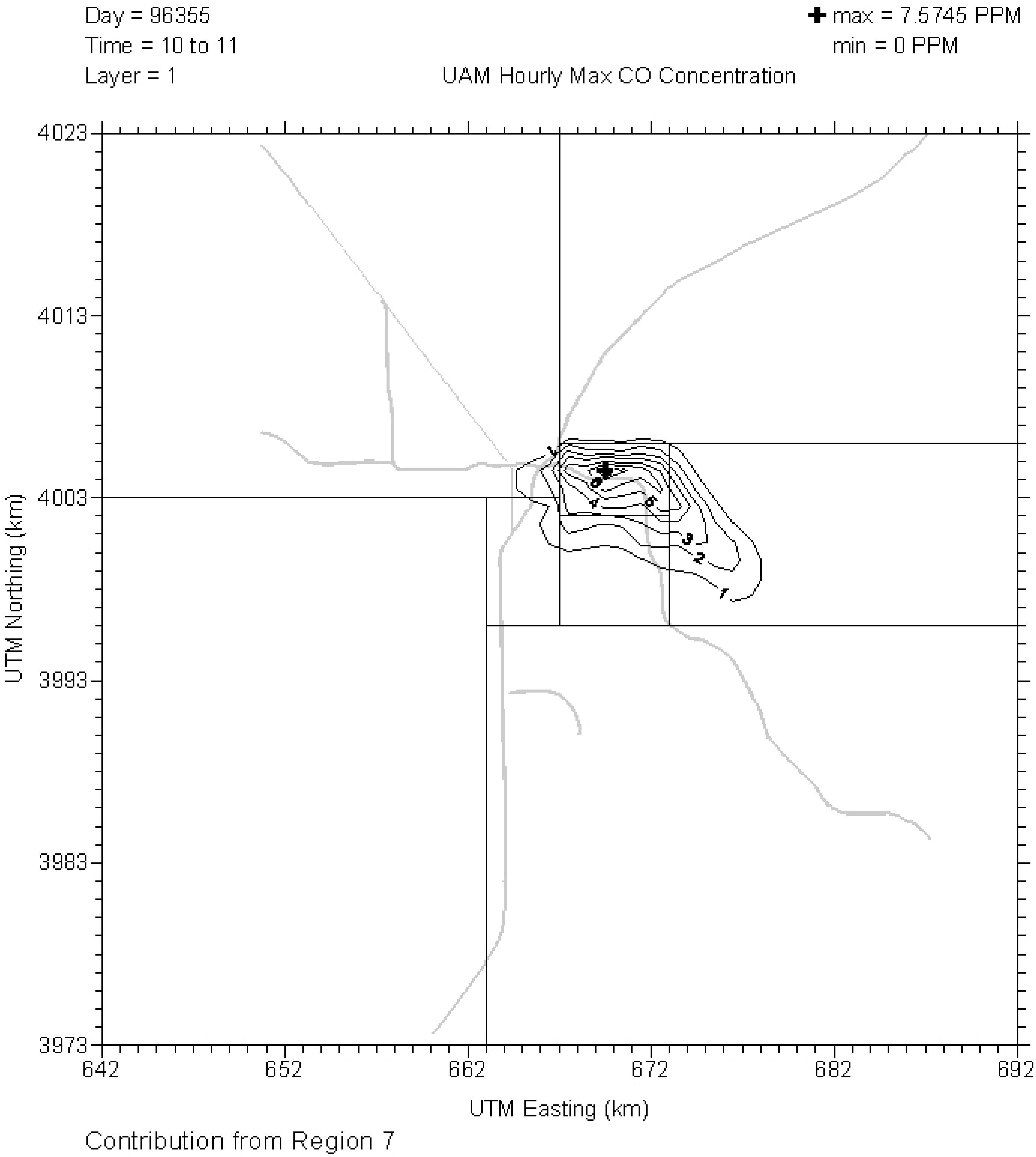

Figure B-8. Contribution of Region 7 to total maximum hourly CO concentration in the December 19-20, 1996 modeling episode.

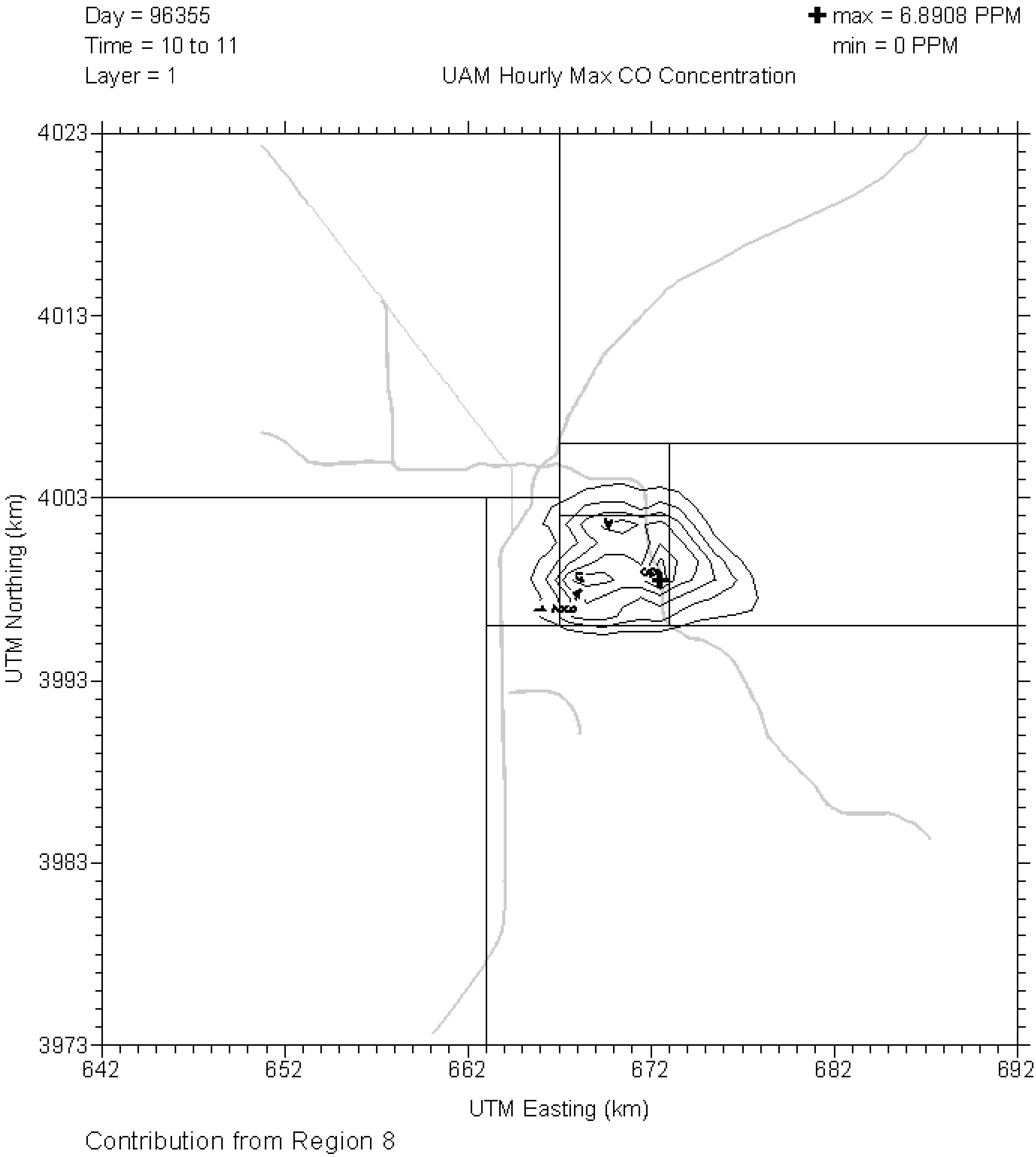

Figure B-9. Contribution of Region 8 to total maximum hourly CO concentration in the December 19-20, 1996 modeling episode.

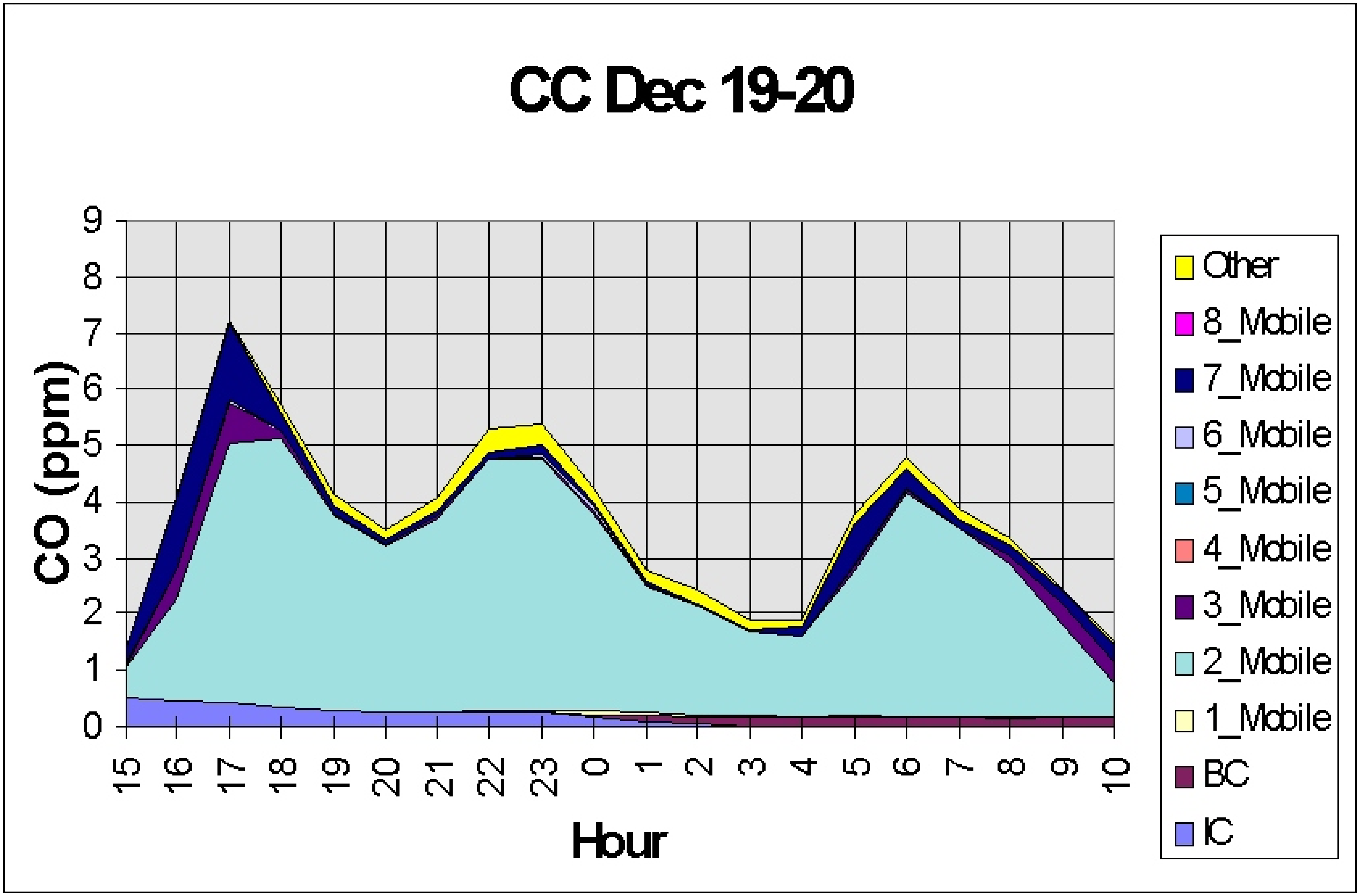

Figure B-10. Time series plot of the contribution from mobile emissions from each source region, total of all remaining emissions, and contributions from initial and boundary conditions at City Center for the December 19-20, 1996 modeling episode.

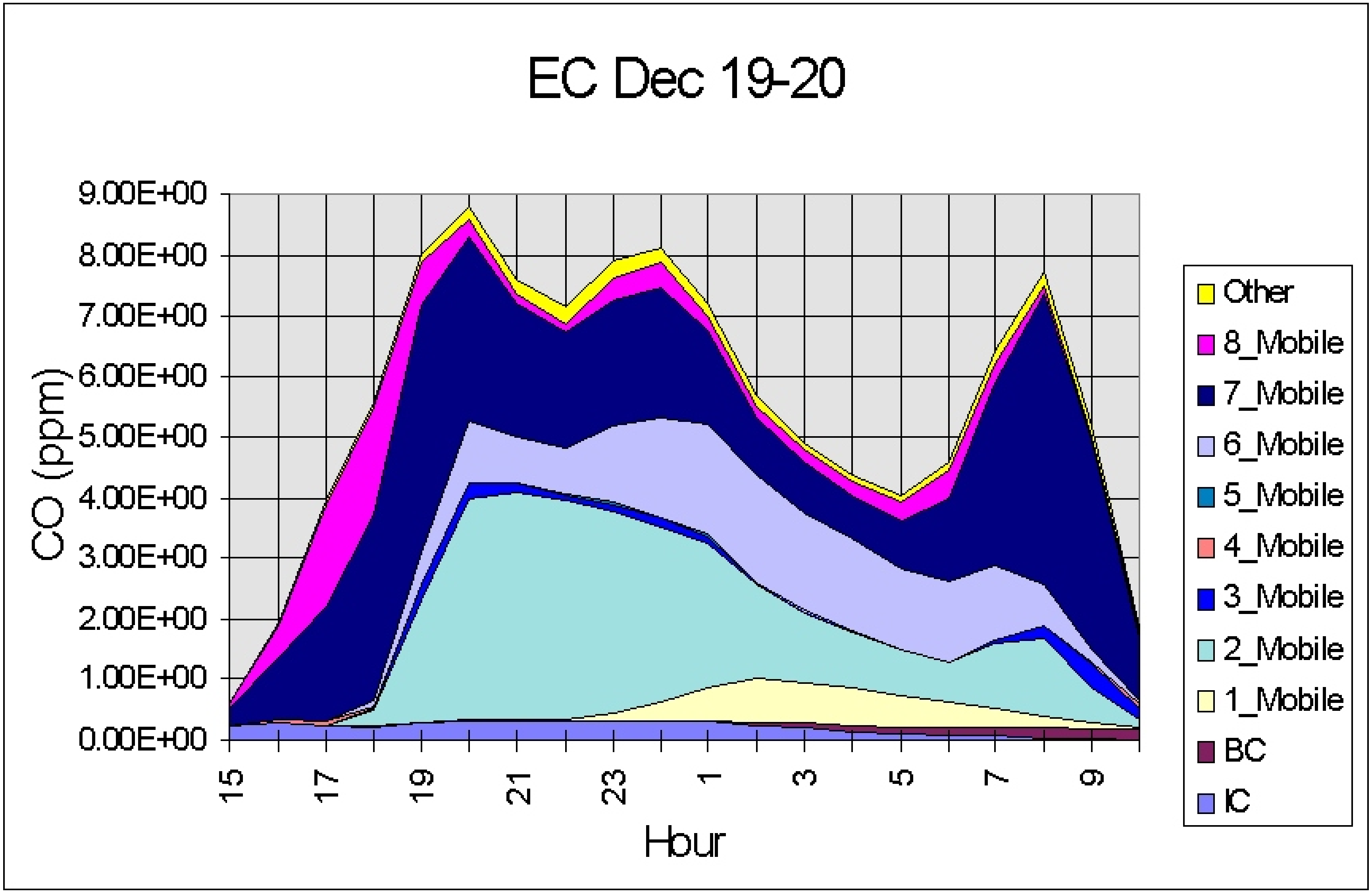

Figure B-11. Time series plot of the contribution from mobile emissions from each source region, total of all remaining emissions, and contributions from initial and boundary conditions at East Charleston for the December 19-20, 1996 modeling episode.

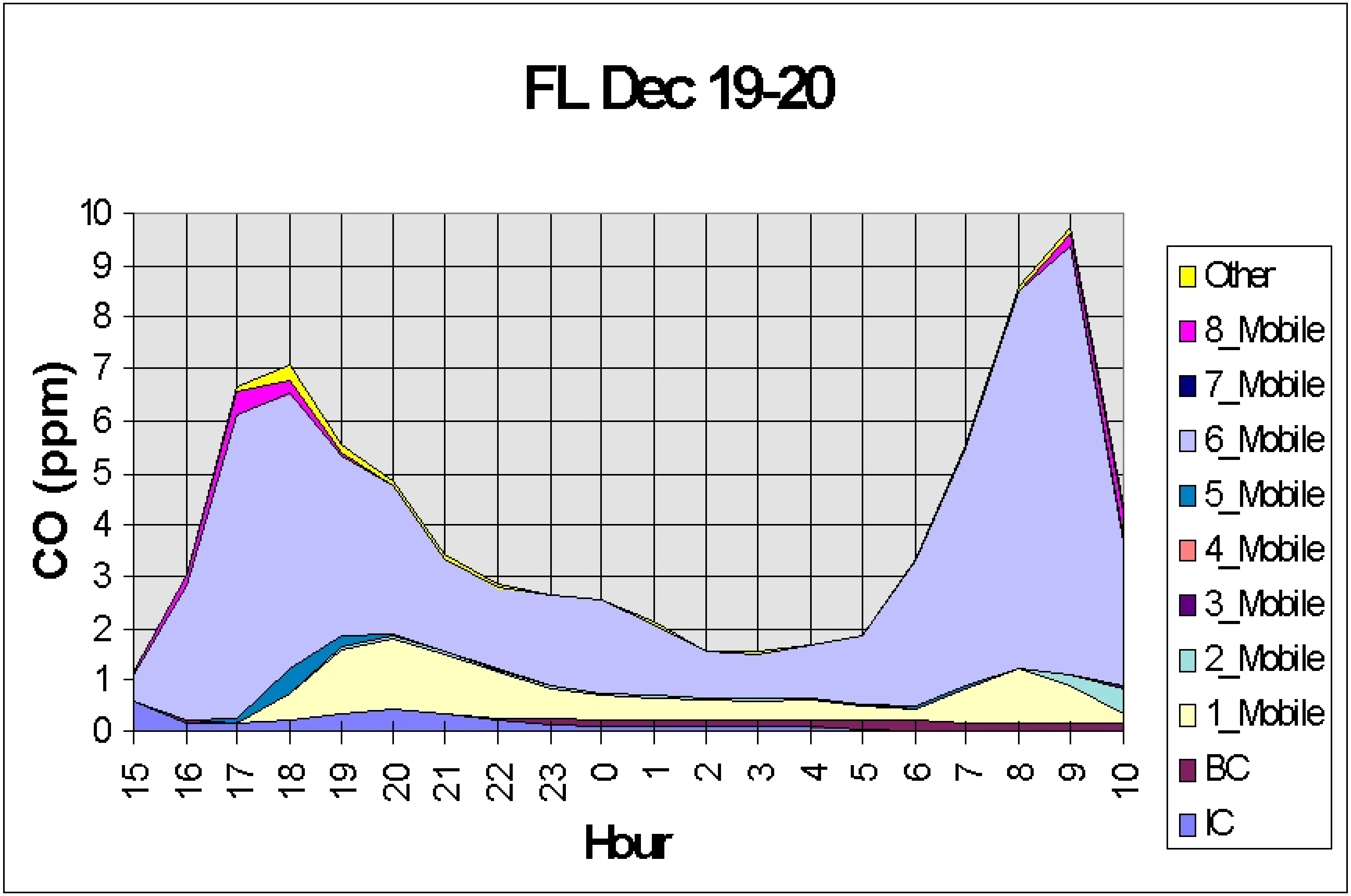

Figure B-12. Time series plot of the contribution from mobile emissions from each source region, total of all remaining emissions, and contributions from initial and boundary conditions at Flamingo for the December 19-20, 1996 modeling episode.

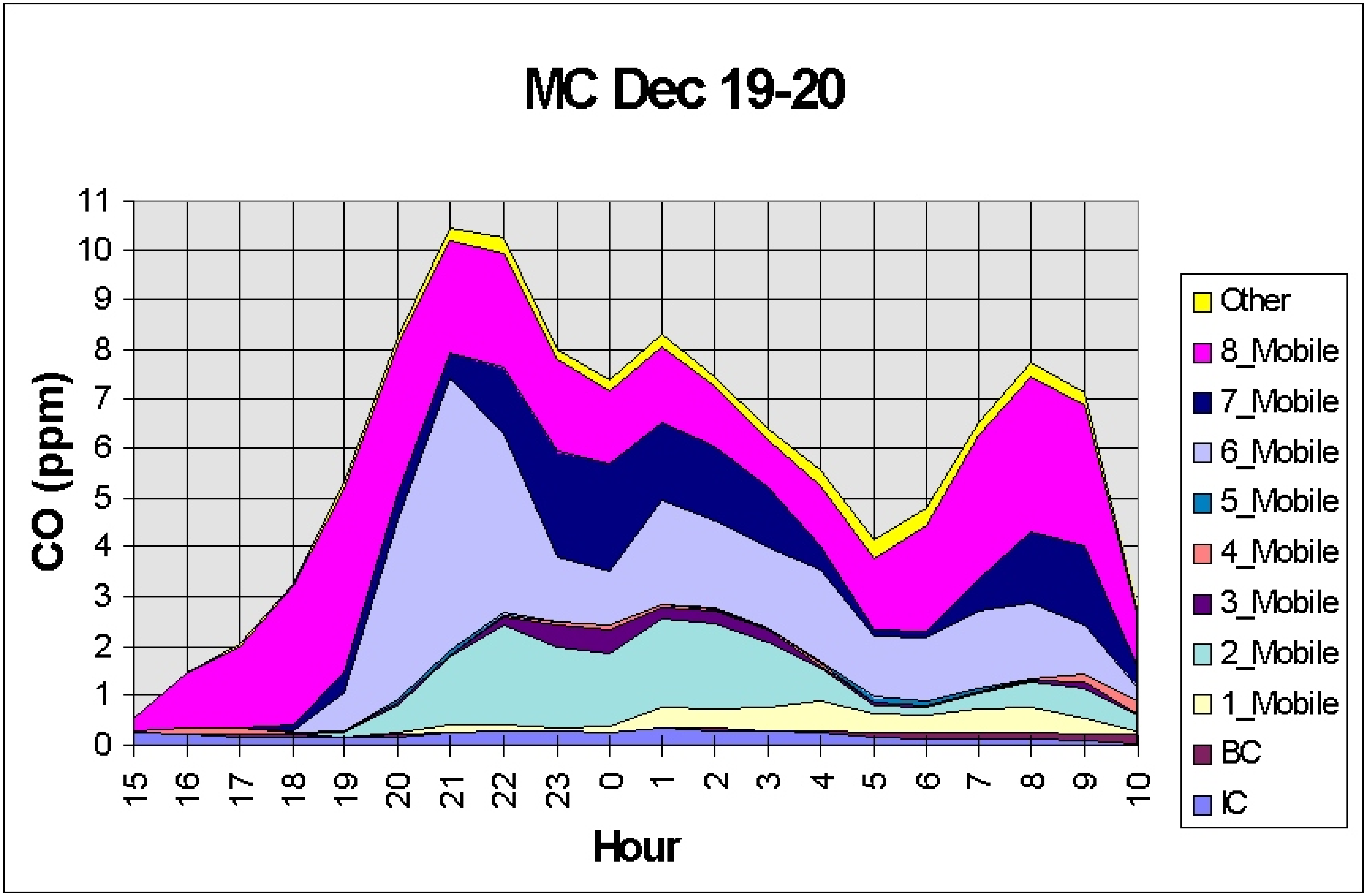

Figure B-13. Time series plot of the contribution from mobile emissions from each source region, total of all remaining emissions, and contributions from initial and boundary conditions at Maycliff for the December 19-20, 1996 modeling episode.

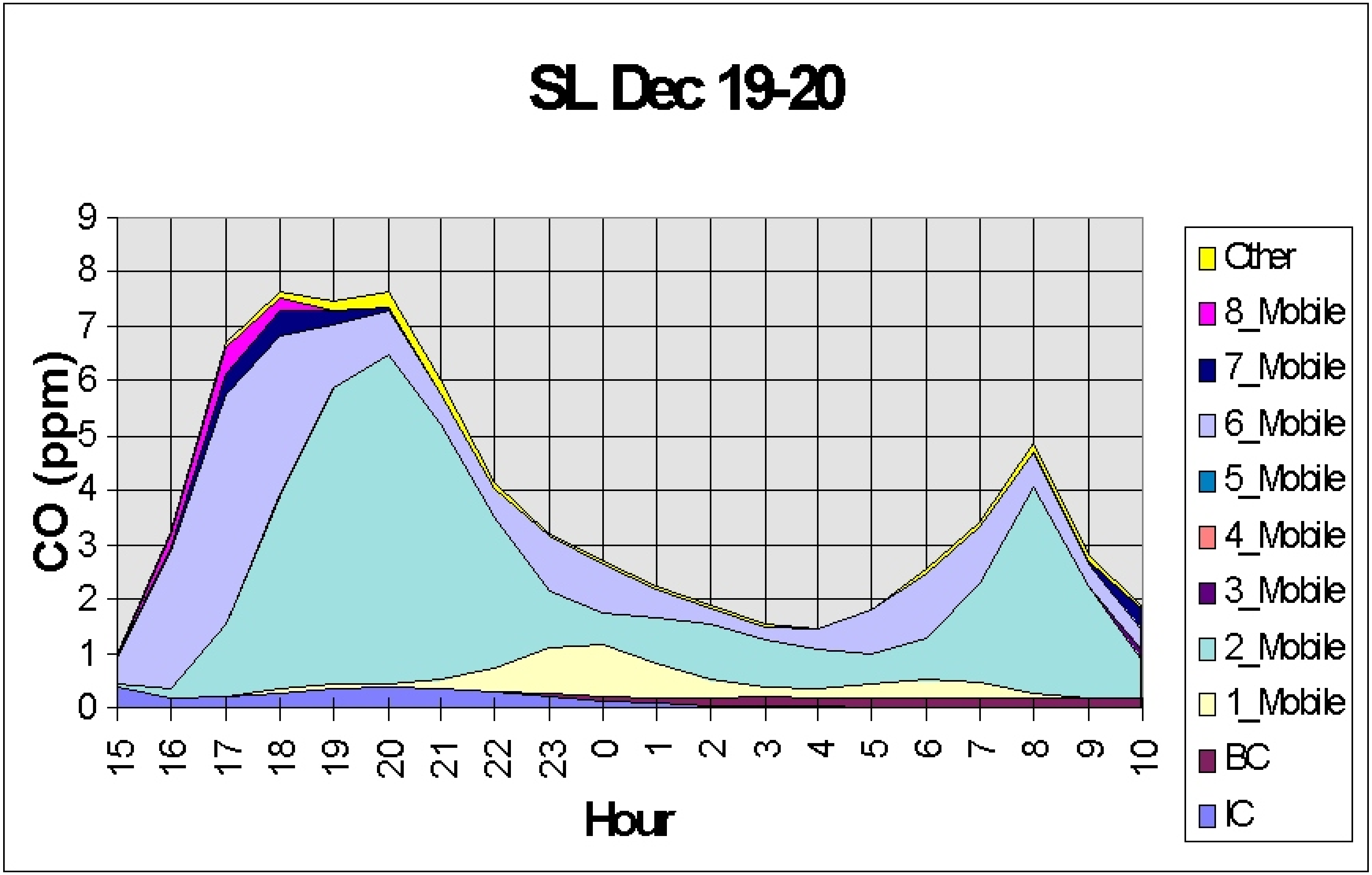

Figure B-14. Time series plot of the contribution from mobile emissions from each source region, total of all remaining emissions, and contributions from initial and boundary conditions at Shadow Lane for the December 19-20, 1996 modeling episode.

APPENDIX C

Section Four
The Las Vegas Valley Carbon Monoxide Urban Airshed Model Update Project – Phase II Modeling to Demonstrate Attainment of the Carbon Monoxide Standard
(Phase 2-final)

Appendix A

Results of Revised Phase II Base Case CO Modeling and
Recommendations of Episode Selection for Future Year Assessments

ENVIRON

MEMORANDUM

To: Scott Bohning, U.S. EPA, Region IX

From: Chris Emery, David Souten

Date: October 8, 1998

cc: Clete Kus, Clark County Department of Comprehensive Planning

Subject: Results of revised Phase II Base Case CO modeling, and recommendation of episode selection for future year assessments

Urban Airshed Model (UAM) simulations for two elevated carbon monoxide (CO) episodes in December 1996 have been carried out using revised on-road motor vehicle emission rates based on the new interim Clark County transportation demand model (TRANPLAN). This memorandum presents a discussion on model performance for these two episodes, and provides our recommendation/rationale on which of these episodes should be carried forward into the future year CO air quality assessments. A recommendation is also made concerning a scaling methodology to bring the chosen episode up to the current Las Vegas CO design value.

The two CO modeling episodes consist of the overnight periods (3 PM to 11 AM) between December 8-9 and 19-20, 1996; these episodes were selected from the intensive CO Field Study undertaken during Phase II of the Las Vegas Valley CO Urban Airshed Model Update Project. Daily roadway link-specific traffic volumes (in terms of vehicle miles traveled, or VMT) were determined from the interim 1996 TRANPLAN model, based on the definition of 751 traffic analysis zones (TAZ). Currently, TRANPLAN is being further improved by redefining the traffic network for 1140 TAZ. The daily VMT data were allocated to day of week (weekday vs. weekend) and to each hour, based on basin-wide average traffic count profiles from the Nevada Department of Transportation (NDOT). The Direct Travel Impact Model (DTIM2) was used to determine link-specific mobile emissions by combining the diurnal VMT profiles and episode hourly temperatures with fleet emission rates estimated by MOBILE5a; DTIM2 then translates link-specific emissions to the modeling grid. The resulting hourly gridded on-road motor vehicle CO emission rates were then merged with stationary, non-road, and point source CO emissions data (which were unchanged from original Phase II Base Case estimates) to provide complete emissions inputs for UAM.

Model Performance

UAM performance in replicating measured CO patterns temporally and spatially are described here in the following contexts:

1) Improvements/degradation of statistical performance relative to the original Phase II December 1996 Base Case runs;

2) Meeting EPA guidance criteria for acceptable model performance (which focuses on UAM ability to replicate magnitude and timing of peak concentrations);

3) Overall bias and error; and

4) Graphical representations of the spatial distribution of predicted and observed 8-hour maximum CO and comparisons to the conceptual model of CO buildup on the Las Vegas Valley.

Table 1 presents the pertinent model performance statistics for the December 8-9 episode. The summary is split between statistics derived using all available County and special Phase II Field Study measurement data, and statistics derived using just County measurements. Also, statistics in both cases are presented for 1-hour and 8-hour average CO concentrations. Note that only 8-hour statistics are addressed by the EPA performance criteria; therefore, the discussions that follow focus on 8-hour CO performance. Finally, statistics are provided for the original Phase II Base Case runs and the current revised runs for comparative purposes.

The colored boxes in Table 1 highlight the 8-hour statistics that are relevant to EPA acceptance criteria. EPA (1992) states that the following conditions must be met to consider model performance acceptable for CO attainment demonstrations:

1) The unpaired peak prediction accuracy (UPPA, a comparison between the peak measurement and the peak predicted concentration anywhere in the domain at any time) must be within ±**30-35%**;

2) The average gross error among paired peaks (in space and time) above 5 ppm must be within **20-25%**;

3) The average gross error in the timing of the peaks among all sites above 5 ppm must be within **2 hours**.

The colored boxes in Table 1 indicate the status of meeting these criteria: green indicates a statistical value that is inside the outer range for acceptance, yellow indicates a value that is within the outer range but is still acceptable, and red indicates a value that is outside the range.

The peak measured 8-hour CO concentration for the December 8-9 episode (9.6 ppm) occurred at Marnell Field (a special Field Study site). The peak predicted 8-hour CO anywhere in the domain is 8.8 ppm and occurs in a cell just to the northwest of Marnell Field along U.S. 95, leading to a UPPA score of -8%. The peak prediction at Marnell Field is 7.2 ppm, leading to a peak prediction accuracy (PPA) score -25%, with zero error in the timing of the peak. If we consider only County sites, the peak measured 8-hour CO is 7.9 ppm at Sunrise Acres. The model under predicts this value (6.9 ppm, -12% PPA), but also exhibits zero error in timing.

Focusing on the 8-hour statistics for December 8-9, model performance over all Phase II monitoring sites has improved in the revised run. Also, the average gross error in peaks has moved into the range for acceptable performance. Two out of three EPA model performance criteria are met, with the gross timing error outside the acceptable range by 1 hour. In the case in which performance is measured for just County sites, statistics have also markedly improved and all three EPA model performance criteria are met.

Figure 4 displays the 8-hour maximum predicted CO pattern in the domain for the December 8-9 episode, with peak 8-hour measurements overlaid. The spatial agreement in the prediction and measurement patterns is rather good (especially the location of the domain peak), but a general under prediction is seen in the magnitudes. The largest obvious problem is the drastic under prediction of the 9.5 ppm (rounded to 10 ppm) measurement at Eastern and Owens (a special Field Study site).

Table 2 presents a similar set of statistics for the December 19-20 episode. Again, the measured peak 8-hour CO occurs at Marnell Field, but the predicted peak anywhere in the domain occurs between I-15 and Las Vegas Boulevard near Spring Mountain Road. The unpaired peak prediction of 11.3 ppm leads to a UPPA score of +19%, which is much higher than in the original run. The paired 8-hour maximum predicted CO is only 7.5 ppm, leading to the same -22% PPA score as in the original run and the same 7 hour error in timing. Considering only County monitoring sites, the peak measured 8-hour CO is 8.0 at Sunrise Acres, which leads to a UPPA score (+42%) that is outside the range for acceptable model performance. The PPA score at Sunrise Acres is quite good at -6%, but the error in timing is 6 hours. Overall, model performance remains constant or improves slightly for the December 19-20 episode.

Figure 5 displays the 8-hour maximum predicted CO pattern and measurements for the December 19-20 episode. The predicted domain peak is seen in the Las Vegas Boulevard area, and a rather extensive high CO plume extends eastward to U.S. 95 about 8 km away. The measurements that exist around the edges of this plume are mostly over predicted (e.g., compare the Flamingo value of 4 ppm to predictions of 6-7 ppm), which suggests that this high CO area may be a large over prediction. The under prediction of the measured peak at Marnell Field is obvious, however the surrounding measurements of 6-8 ppm are well replicated. In general, the spatial agreement between predictions and observations is not as close as in the December 8-9 episode.
Comparisons between the observations and the prediction pattern shows that the two CO patterns do not agree well, particularly around the area of Sunrise Acres. The comparison becomes much more favorable for the December 8-9 episode.

It is difficult to pinpoint the reasons for the very high unsubstantiated modeled CO peak in the area of Spring Mountain Road, I-15, and Las Vegas Boulevard during the December 19-20 episode. There are two main reasons why emissions are likely to be lower in the Spring Mountain Road area in the December 8-9 episode: (1) December 8 was a Sunday, and mobile emission rates through midnight on December 9 have been uniformly scaled down to reflect the expected lower activity on weekend days; and (2) this episode was characterized by warmer nighttime temperatures (minimum 44 F on December 9 versus minimum 29 F on December 20 at McCarran Airport), which reduce the CO emission rates from motor vehicles. Certainly there is also the possibility that emissions in the Spring Mountain Road area suffer from a number of large uncertainties. These would include unrealistic VMT in this area as diagnosed from TRANPLAN output, vehicle emission rates that are overly sensitive to temperature as defined by MOBILE5, and the artificial combination/movement of emissions from various links into single grid cells during DTIM2 processing.

Different meteorology among the two episodes is likely playing a role in the subsequent transport of the elevated CO cloud from the Spring Mountain area. The inversion depths and static stability (temperature lapse rates) specified for UAM are very similar among the two episodes, so it is not likely that these parameters are contributing a significant impact. It is more likely related to an increased level of stagnation (low wind speeds) in that area during the night of December 19-20, enhancing the buildup of CO into the morning commute hours. Modeled winds are quite uncertain in that area since they are based purely on a smoothed interpolation of wind measurements from several kilometers away.

It is therefore quite possible that the overall peak CO in the December 19-20 episode is not well modeled and far too high. As mentioned above, peak 8-hour observations surrounding the resulting CO plume are much lower than predicted (even for a *micro-scale* site on Las Vegas Boulevard just to the south), giving a clue to the over prediction. It should also be noted that the Clark County Health District (Air Pollution Control District) had performed temporary CO monitoring in this area during the winter of 1994 (based on similarly high concentrations predicted in earlier UAM SIP modeling) but had found no evidence of such CO levels. The December 19-20 modeling results therefore do not conform to our conceptual model of CO buildup in the Las Vegas Valley.

Recommendations

In modeling the impacts of future year growth and control strategies, it will be necessary to demonstrate that the Las Vegas CO "design value" is reduced to or below the 8-hour standard of 9 ppm (or alternatively, below 9.5 ppm, which rounds down to the whole number standard). The design value is taken from the latest official 8-hour CO violation measured in the basin; the current value is 10.2 ppm, which occurred during the night of January 5-6, 1996 at East Charleston. None of the Phase II Field Study episodes exceeded the 8-hour standard according to County measurements. However, several special Field Study monitors did record concentrations above 9 ppm for both modeling episodes. During the December 8-9 episode, three sites recorded CO at or above the standard, with a maximum of 9.6 ppm; during December 19-20, a single site recorded a maximum of 9.5 ppm. In any event, peak CO measurements are lower than the current Las Vegas design value.

The Phase II episodes provide an extensive meteorological and air quality database that offer significantly improved environmental inputs and enhanced performance appraisal capabilities over those which are available for any other historical episode. This drastically increases our confidence that the UAM is replicating Phase II CO patterns in the areas of East Charleston for appropriate reasons, consistent with ambient conditions. Further, it has been shown (Emery et al., 1998) that the conditions observed during both Phase II modeling episodes adequately characterize the environment that induces CO buildup to exceedance levels in the Las Vegas basin. Therefore, these episodes should be considered to be as representative as any other past exceedance event, and it is recommended that the demonstration of a Las Vegas CO implementation plan be based upon Phase II UAM applications.

To move forward with the Phase II modeling episodes in evaluating the impacts of future year growth and controls, it will be necessary to express changes in peak predicted CO in terms of relative impacts to the design value. This can be accomplished through the use of a scaling factor. It is sometimes necessary to define two separate factors: (1) to shift peak predictions to peak measurements in the case of a UAM under prediction bias (as seen in UAM performance under Phase II); and (2) to scale up matched predictions and measurements by the relative difference between the peak CO defining a particular episode and the design value.

We further recommend that a single Phase II modeling episode be used as Clark County moves forward with future year assessments of control strategies, growth projections, and attainment/conformity status. This reduces complications associated with varying model performance among multiple episodes, and thus the necessity of developing different scaling approaches for each episode. Hence, the modeling episode to be used must represent the best overall performance, especially in terms of its ability to replicate measured CO peaks both spatially and in magnitude.

After closely studying the results that are briefly described above, we conclude that the December 8-9 episode should be selected for the remainder of the analyses. Compared to the December 19-20 episode, the former exhibits the following advantages: (1) three measurements over the 9 ppm standard (at special Field Study sites) rather than one; (2) better model performance in matching the spatial distribution of peak measured CO; (3) model performance meets all three EPA guidance criteria (based upon comparisons to County measurements); and (4) conforms to our conceptual model for CO buildup.

While the December 8-9 episode meets the EPA model performance criterion for gross error in the timing of peak CO based on County measurements above 5 ppm, it does not meet this criterion based on all available Phase II measurements. We do not believe this to be a serious issue, however. Measurements indicate that most sites are characterized by both high evening and morning peak CO of similar magnitude. The model performs well in replicating both maxima; however, at four out of twelve sites reporting peak 8-hour CO above 5 ppm the model predicts the highest CO for one of the peaks while the measurements indicate maximum CO for the opposite peak. This results in small error in peak magnitudes unpaired in time, but 7-8 hour differences in the peak timing. The key is that the peak predictions for all sites in the East Charleston/Sunrise Acres area (the “limiting” monitors for control strategy development) exhibit 0-1 hour timing differences for December 8-9.

Scaling

The negative bias in UAM predictive performance associated with the December 8-9 episode is rather uniform across a number of metrics. More specifically, the PPA score, the bias in paired (time and space) peaks over all Phase II sites, and the overall model bias are all about -25%. This suggests that some consistent error in the modeling (most likely a under estimation of emission rates) is driving the UAM under prediction, and that a single factor of 1.33 will lead to the elimination of these biases and improve overall performance. Indeed, when this factor is applied to all predicted CO concentrations output by the model, the statistics are greatly improved (Table 3).

Note that scaling up the maximum CO predicted anywhere in the domain (8.8 ppm) results in an overall peak of 11.6 ppm, which is well above the current Las Vegas CO design value of 10.2 ppm. Therefore, there is no need to develop the second component of the scaling factor, i.e., to further raise the 1996 Base Case prediction-observation set to the design value. We recommend that the remainder of the CO modeling analyses focus on reducing the scaled unpaired peak to the attainment level. This approach leads to a conservative analysis by requiring a larger CO concentration reduction (18%) to reach attainment than would be necessary to reduce the design value (7%).

In effect, therefore, we are saying that the new design value is 11.6 ppm rather than 10.2 ppm. There are several ways of looking at this. We have historically always seen emissions to be under estimated, and that leads to underpredictions of ambient CO concentrations. Preliminary T2AT analyses (undertaken by Clark County) suggest that the base year (1996) emissions developed from MOBILE5 are indeed low by about 20-25%. So our scaling factor is not out of line with this likely underprediction of emissions. Another consideration is that it has been possible to monitor higher CO concentrations elsewhere in the basin than are measured by the standard density of official monitors, and this was true during the Phase II field study. Thus, it would not be surprising if in fact there are areas in the Valley in which CO builds up to higher concentrations. Another consideration is the December 19-20 episode: while we believe that it is not the best episode for use in the SIP plan because we have no clear evidence of the very high value that is predicted for that episode, and it appears to be an anomaly based on measurements, it is possible that there is some underlying partial-truth to the predicted concentrations (i.e., some microscale meteorological or emission effect). Thus some factor or safety margin in the emissions reductions derived from the Dec 8-9 modeling may be in order.

Given the air planning community's (nationwide) past record of seldom, if ever, accomplishing the emissions reductions that were expected, some conservatism would seem prudent. Lastly, if we are to believe the (perhaps optimistic) predictions that T2AT seems to suggest for future year automobile fleet emissions reductions and durability, the increased emission reduction requirements that results from the use of the 11.6 ppm design value may be more than compensated by the T2AT predicted emissions reductions. As we go forward in our estimates of future year base-case emissions and air quality, we will certainly see the effects of the fleet turnover, whether with MOBILE5, T2AT, or MOBILE6. This will provide some insight into the range of effects stemming from uncertainties in the mobile source emissions factor models. However, it is important to recognize that we will not have any such insight on the uncertainty in the VMT estimates. It would be very useful to explore past estimates of future year VMT, and compare them to later actuals or re-estimates to give some additional insight into the uncertainty in the VMT-derived emissions (and resulting ambient CO levels). Alternatively, a very rough approximation of the range of possible VMT could be derived by scaling future VMT estimates according to a range of population growth assumptions as projected by the State of Nevada.

References

Emery, C., D. Souten, N. Kumar, F. Lurmann, P. Roberts. 1998. The Las Vegas Valley Carbon Monoxide Urban Airshed Model Update Project – Phase II: UAM Base Case and Sensitivity Applications. Prepared for the Clark County Department of Comprehensive Planning, by ENVIRON International Corporation, Novato, CA, and Sonoma Technology, Inc., Santa Rosa, CA.

EPA. 1992. *Guideline for Regulatory Application of the Urban Airshed Model for Areawide CO Applications*. EPA-450/4-92-011a&b, Research Triangle Park, NC.

Table 1. Model Performance statistics for the December 8-9 Phase II modeling episode, based upon measured CO concentrations above 5 ppm. See text for full description.

December 8-9, 1996

Model Performance Statistics for All Sites

	1-hour	8-hour
Peak Obs (ppm)	13.8	9.6
Peak Site (ppm)	MF	MF
Avg Obs (ppm)	3.9	4.1

	Original Run (Phase II)		Revised Run (Phase IIb)	
	1-hour	8-hour	1-hour	8-hour
Unpaired Peak (ppm)	12.7	8.0	14.8	8.8
Paired Peak (ppm)	8.1	6.8	8.3	7.2
Avg Prediction (ppm)	3.2	3.4	3.5	3.7
UPPA (%)	-8	-16	7	-8
PPA (space, not time) (%)	-41	-29	-40	-25
PPA Timing Error (hr)	1	0	1	0
Bias in Peaks (%)	-30	-29	-25	-24
Error in Peaks (%)	35	29	32	-24
Timing Bias (hr)	-3	-1	-4	-1
Timing Error (hr)	4	3	5	3
Overall Bias (%)	-28	-30	-22	-24
Overall Error (%)	32	30	28	25

Model Performance Statistics for APCD Sites Only

	1-hour	8-hour
Peak Obs (ppm)	11.8	7.9
Peak Site (ppm)	SA	SA
Avg Obs (ppm)	3.1	3.1

	Original Run (Phase II)		Revised Run (Phase IIb)	
	1-hour	8-hour	1-hour	8-hour
Unpaired Peak (ppm)	12.7	8.0	14.8	8.8
Paired Peak (ppm)	7.9	6.6	8.1	6.9
Avg Prediction (ppm)	2.7	2.8	2.9	3.0
UPPA (%)	8	2	25	11
PPA (space, not time) (%)	-33	-16	-32	-12
PPA Timing Error (hr)	1	0	-9	0
Bias in Peaks (%)	-25	-21	-20	-15
Error in Peaks (%)	36	21	36	15
Timing Bias (hr)	-4	-1	-7	-1
Timing Error (hr)	5	2	7	2
Overall Bias (%)	-21	-21	-15	-16
Overall Error (%)	27	21	25	17

Table 2. Model Performance statistics for the December 19-20 Phase II modeling episode based upon measured CO concentrations above 5 ppm. See text for full description.

December 19-20, 1996

Model Performance Statistics for All Sites

	1-hour	8-hour
Peak Obs (ppm)	14.3	9.5
Peak Site (ppm)	EO	MF
Avg Obs (ppm)	3.9	4.2

	Original Run (Phase II)		Revised Run (Phase IIb)	
	1-hour	8-hour	1-hour	8-hour
Unpaired Peak (ppm)	14.0	9.6	15.3	11.3
Paired Peak (ppm)	3.2	7.4	3.7	7.5
Avg Prediction (ppm)	3.6	3.8	3.8	4.0
UPPA (%)	-2	1	7	19
PPA (space, not time) (%)	-77	-22	-74	-22
PPA Timing Error (hr)	-12	-7	-12	-7
Bias in Peaks (%)	-31	-19	-26	-14
Error in Peaks (%)	31	24	28	22
Timing Bias (hr)	-7	-3	-6	-2
Timing Error (hr)	8	3	7	4
Overall Bias (%)	-20	-17	-15	-12
Overall Error (%)	30	23	28	19

Model Performance Statistics for APCD Sites Only

	1-hour	8-hour
Peak Obs (ppm)	10.8	8.0
Peak Site (ppm)	SA	SA
Avg Obs (ppm)	3.3	3.5

	Original Run (Phase II)		Revised Run (Phase IIb)	
	1-hour	8-hour	1-hour	8-hour
Unpaired Peak (ppm)	14.0	9.6	15.3	11.3
Paired Peak (ppm)	9.3	7.7	9.4	7.6
Avg Prediction (ppm)	3.2	3.3	3.4	3.5
UPPA (%)	30	20	41	42
PPA (space, not time) (%)	-14	-4	-13	-6
PPA Timing Error (hr)	-12	-6	1	-6
Bias in Peaks (%)	-27	-6	-25	-2
Error in Peaks (%)	28	18	25	16
Timing Bias (hr)	-5	-3	-3	-1
Timing Error (hr)	6	3	5	4
Overall Bias (%)	-8	-3	-5	1
Overall Error (%)	24	15	25	12

Table 3. Model Performance statistics for the December 8-9 Phase II modeling episode after UAM predictions have been scaled by 1.33. See text for full description.

December 8-9, 1996

Model Performance Statistics for All Sites		
	1-hour	8-hour
Peak Obs (ppm)	13.8	9.6
Peak Site (ppm)	MF	MF
Avg Obs (ppm)	3.9	4.1
	Phase IIb scaled by 1.33	
	1-hour	8-hour
Unpaired Peak (ppm)	19.7	11.6
Paired Peak (ppm)	11.1	9.6
Avg Prediction (ppm)	4.6	5.0
UPPA (%)	43	22
PPA (space, not time) (%)	-20	0
PPA Timing Error (hr)	1	0
Bias in Peaks (%)	0	2
Error in Peaks (%)	26	13
Timing Bias (hr)	-4	-1
Timing Error (hr)	5	3
Overall Bias (%)	3	1
Overall Error (%)	26	17

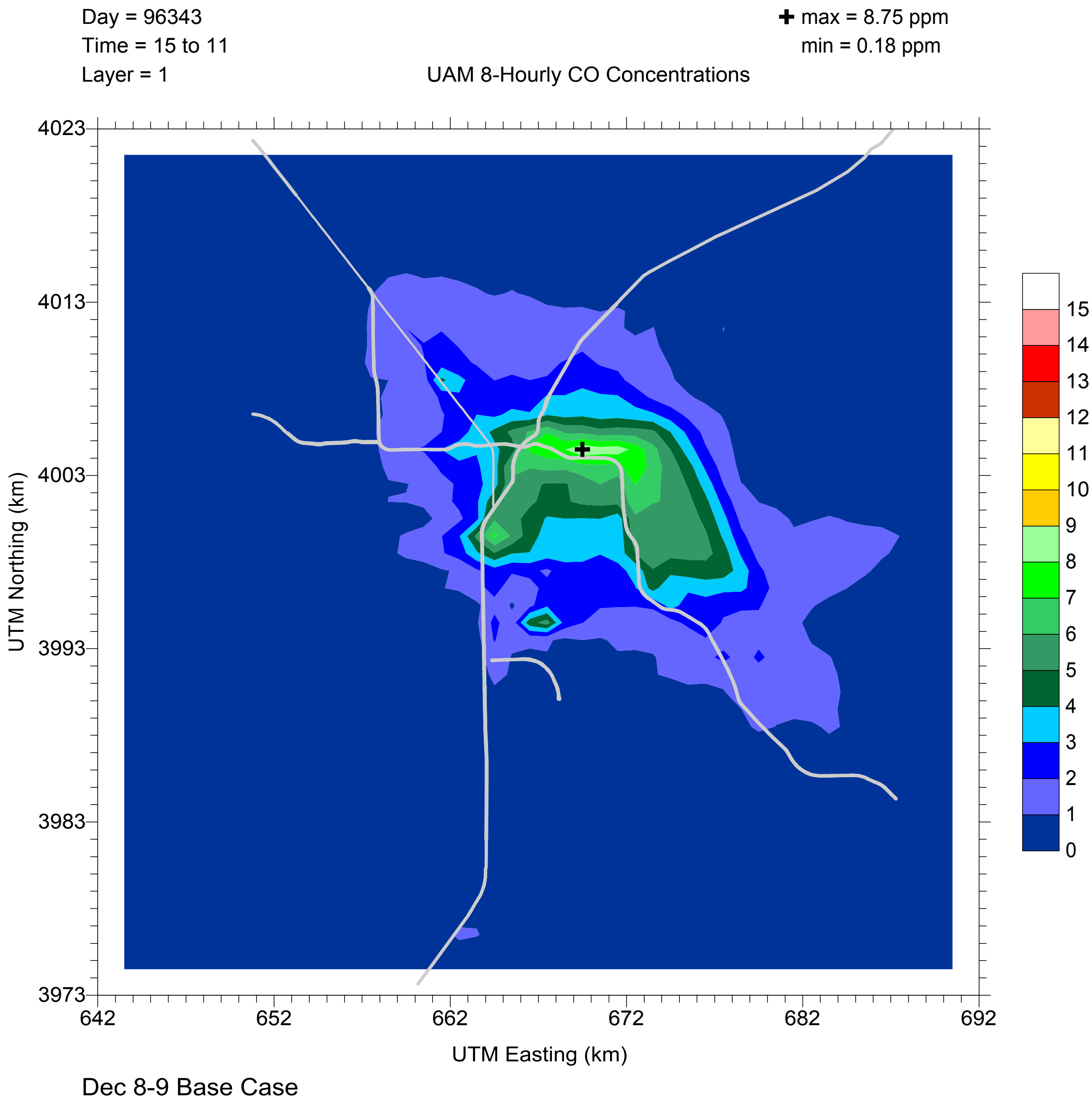

Figure 4. Spatial distribution of episode-maximum 8-hour CO concentrations (ppm) simulated for the December 8-9, 1996 Phase IIb episode.

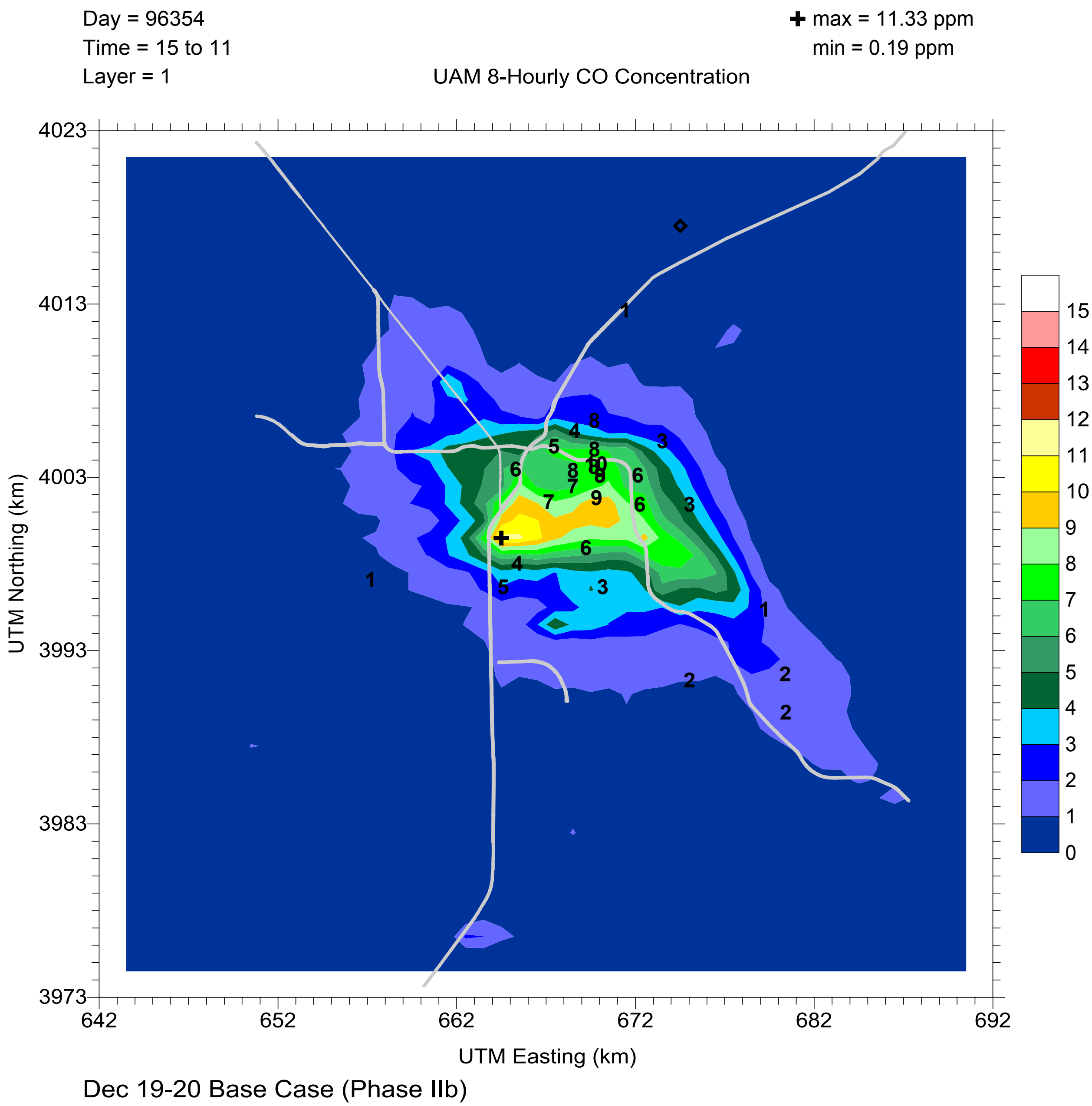

Figure 5. Spatial distribution of episode-maximum 8-hour CO concentrations (ppm) simulated for the December 19-20, 1996 Phase IIb episode.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, Ca. 94105-3901

October 27, 1998

Clete Kus
Clark County Department
of Comprehensive Planning
500 South Grand Central Parkway, Suite 3012
P.O. Box 551741
Las Vegas, NV 89155-1741

Dear Clete,

Thank you for the opportunity last week to discuss the carbon monoxide (CO) modeling for Clark County. As I stated on the October 20th call, I feel that the interpretations and approaches outlined in the Environ memorandum of October 8th are acceptable as the basis for developing a CO State Implementation Plan (SIP).

In particular, despite some problems in the performance statistics for the Urban Airshed Model (UAM), it seems to be doing fairly well in terms of the overall CO pattern in time and space for the area. Environ has done a good job in using sensitivity simulations to elucidate the functioning of the model. I look forward to seeing additional time series and spatial plots from Environ.

I also agree that, though no discussion of scaling appears in EPA modeling guidance, at this point there is little alternative for SIP development, given the time available and the relatively low CO peak observed in this episode. In former UAM applications for CO, scaling has implicitly been done anyway, through the device of artificially choosing an inversion height. The current application is superior in that it uses real inversion height data. I agree that an underestimated CO emission inventory is a likely cause of the underpredictions. In any case, since CO is an inert pollutant, scaling is less problematic than it would be for ozone.

The proposed scaling approach is a reasonable one. Under this approach, model results are scaled to remove bias, making observations and predictions match at the monitoring sites. The resulting model peak is somewhat higher than Clark County's CO design value, but well within the range of variation that would be expected around that value, and is a plausible model result and basis for control strategy planning.

In summary, I conclude from my review of the initial model results that the proposed approach is as consistent with EPA modeling guidance as it is feasible to be under the current circumstances. I look forward to working with you further as your SIP development work proceeds.

Sincerely,

Scott Bohning

Scott Bohning
Environmental Engineer

cc: Michael Naylor, Clark County Health District
Chris Emery, Environ

APPENDIX C

Section Five
Micro-scale Hot Spot Modeling
with CAL3QHC in Las Vegas

DRAFT

Microscale Hot Spot Modeling With CAL3QHC in Las Vegas

by

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500 S. Grand Central Parkway
PO Box 551741
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January 27, 1999

Introduction

Clark County Department of Comprehensive Planning (CCDCP) has conducted microscale hot spot modeling analysis with CAL3QHC as part of the carbon monoxide (CO) year 2000 attainment demonstration for the Las Vegas Valley non-attainment area. CAL3QHC is a microcomputer based model used to predict CO or inert pollutant concentrations from motor vehicles at roadway intersections, and is the model recommended by the U.S. EPA for CO attainment demonstration.

CO hot spot modeling for three intersections at the "five points" region of Las Vegas has been completed for the episode of December 8-9, 1996 following the modeling protocol and EPA modeling guidelines (EPA, 1992). The "five points" intersections were chosen for the hot spot analysis due to the high-volume of traffic in the area and the high CO concentrations observed in the nearby monitors (Sunrise Acres and Marnel Field) during this episode. The three intersections included in the mircoscale hot spot analysis are:

1) East Charleston and Eastern
2) East Charleston and Fremont
3) Eastern and Fremont

Methodology for Using CAL3QHC

The EPA guidelines recommend the use of combined highest 8-hour running average CO concentrations from the roadway intersection modeling with CAL3QHC (Version 2) and the area-wide models , such as Urban Airshed Model (UAM), for attainment demonstration of CO NAAQS. ENVIRON International Corporation performed the area-wide UAM modeling analysis for the Las Vegas Valley, and provided the UAM results to CCDCP for use in the CAL3QHC analysis. The combined highest 8-hour running average concentration was calculated by the following method:

1) Modeling hourly CO concentrations over the episode period using the CAL3QHC microscale model;

2) Combining 1-hour average microscale CO concentrations with 1-hour average background or neighborhood CO concentrations generated from the UAM in the four grid cells immediately surrounding the roadway intersection;

3) Calculating an 8-hour running average of CO concentrations over the highest continual eight hours.

The input data regarding the intersection geometrics, dimensions, and average signal cycle and times are the same as used in the 1992 CO attainment demonstration modeling generated by BRW (BRW, 1992). Cross-section and link coordinate/receptor diagrams for the three modeled intersections are included in **Appendix A**. Hourly wind speeds and directions from the UAM grid cell where the intersections are located were also used in the CAL3QHC model. Hourly wind speeds and directions at the "five points" intersections are shown in **Table 1**. CAL3QHC user's guide (EPA, 1995) suggests that the wind speed should be at least 1 meter/second (m/s) as

CAL3QHC has not been validated for wind speeds below 1 m/s. Therefore, the default wind speed of 1 m/s was used for the intersection modeling due to the calm wind conditions for the episode. Since the intersections were located in the urban area, the stability class D, as suggested in the EPA guideline, was used for the intersection modeling. Hourly idle and running vehicle emission rates were calculated using MOBILE5b, the same as was used for the UAM modeling. Note that the "off-cycle" emissions were incorporated in the MOBILE5b by ENVIRON for the UAM emission processing.

Table 1 : UAM Hourly Wind Speeds and Directions
December 8 - 9, 1996

Hour	Wind Speed (m/s)	Wind Direction (Degrees)
15 - 16	0.63	130
16 - 17	0.50	180
17 - 18	0.38	170
18 - 19	0.22	250
19 - 20	0.23	240
20 - 21	0.13	270
21 - 22	0.14	180
22 - 23	0.26	250
23 - 24	0.12	270
0 - 1	0.18	240
1 - 2	0.19	270
2 - 3	0.30	250
3 - 4	0.25	240
4 - 5	0.33	240
5 - 6	0.18	240
6 - 7	0.20	220
7 - 8	0.17	270
8 - 9	0.23	80
9 - 10	0.39	100
10 - 11	0.31	180

2000 Primary Control Scenario

The 2000 primary control scenario includes the following control measures:

1) Wintertime Cleaner Burning Gasoline (CBG)
2) Lower Emission Cut Points
3) TCM/TDM
4) Alternative Fuels Program for Government Fleets

Hourly turn movement and approach volumes for the three modeled intersections for the scenario were also derived from those for the 1995 TIP scenario used in the 1992 attainment demonstration modeling. A growth factor of 4% per year from 1995 to 2000 and 3% TCM/TDM control factor were applied to generate the traffic volumes for the year 2000 primary control scenario. Hourly turn movement volumes for the three modeled intersections for the year 2000 primary control scenario are presented in **Appendix B**.

Since MOBILE5b cannot directly estimate the benefits of primary control measures such as CBG, alternative fuels, and lower emission cut point programs, the emission rates were calculated first with MOBILE5b without the benefits of the proposed primary controls, and then were adjusted with control factors to account for the benefits of these controls. The control factors are based on those used for UAM modeling. Hourly temperatures utilized for the episode were consistent with the UAM emission processing. The running and idle vehicle emission rates along with hourly temperatures and free flow speeds used as inputs to CAL3QHC are shown in **Table 2**.

Table 2 : Hourly Emission Rates, Temperatures and Free Flow Speeds
December 8 - 9, 1996

Hour	**Air Temperature (F)**	**Free Flow Speed (MPH)**	**Running Emission Rate (g/mile)**	**Idle Emission Rates (g/hr)**
15 - 16	66	35	7.2	161
16 - 17	62	35	7.7	171
17 - 18	58	35	8.0	180
18 - 19	55	35	8.4	188
19 - 20	53	35	8.9	200
20 - 21	51	35	8.9	199
21 - 22	50	35	8.7	195
22 - 23	48	35	8.8	196
23 - 24	47	35	8.8	196
0 - 1	45	35	8.8	196
1 - 2	44	35	9.0	201
2 - 3	44	35	8.9	198
3 - 4	43	35	9.0	201
4 - 5	42	35	8.8	195
5 - 6	42	35	8.8	196
6 - 7	42	35	8.8	196
7 - 8	44	35	8.8	197
8 - 9	49	35	8.5	189
9 - 10	51	35	8.9	200
10 - 11	55	35	8.8	196

Modeling Results

Table 3 summarizes the area-wide and mircoscale CO concentrations predicted from UAM and CAL3QHC for the 2000 primary control scenario. Both 1-hour and 8-hour CAL3QHC + UAM concentrations by intersection are presented in **Appendix C**.

The combined results in **Table 3** show that the predicted 8-hour maximum CO concentration is 8.8 ppm at the Eastern and Charleston intersection. According to EPA's guidance, the combined results from the roadway intersection modeling and the area-wide modeling should show no predicted 8-hour maximum concentrations greater than 9.0 ppm in order to demonstrate attainment of the CO NAAQS. Therefore, we believe that the 2000 primary controls will result in sufficient emission reductions to reach attainment of the CO NAAQS in the Las Vegas Valley.

Table 3 : Maximum 8-Hour CO Concentrations at Five Point Intersections
December 8 - 9, 1996

Intersections	Maximum UAM +CAL3Q (ppm)	Maximum UAM (ppm)
Charleston/Eastern	8.8	5.9
Charleston/Fremont	6.9	5.9
Eastern/Fremont	7.7	5.9

References

BRW. 1992. Las Vegas Air quality Implementation Plan Update, Phase II: Carbon Monoxide Modeling and Attainment Demonstration. Prepared for Clark County Department of Comprehensive Planning. Prepared by BRW, Inc., San Diego, CA and System Applications, Inc., San Rafael, CA. November 6, 1992.

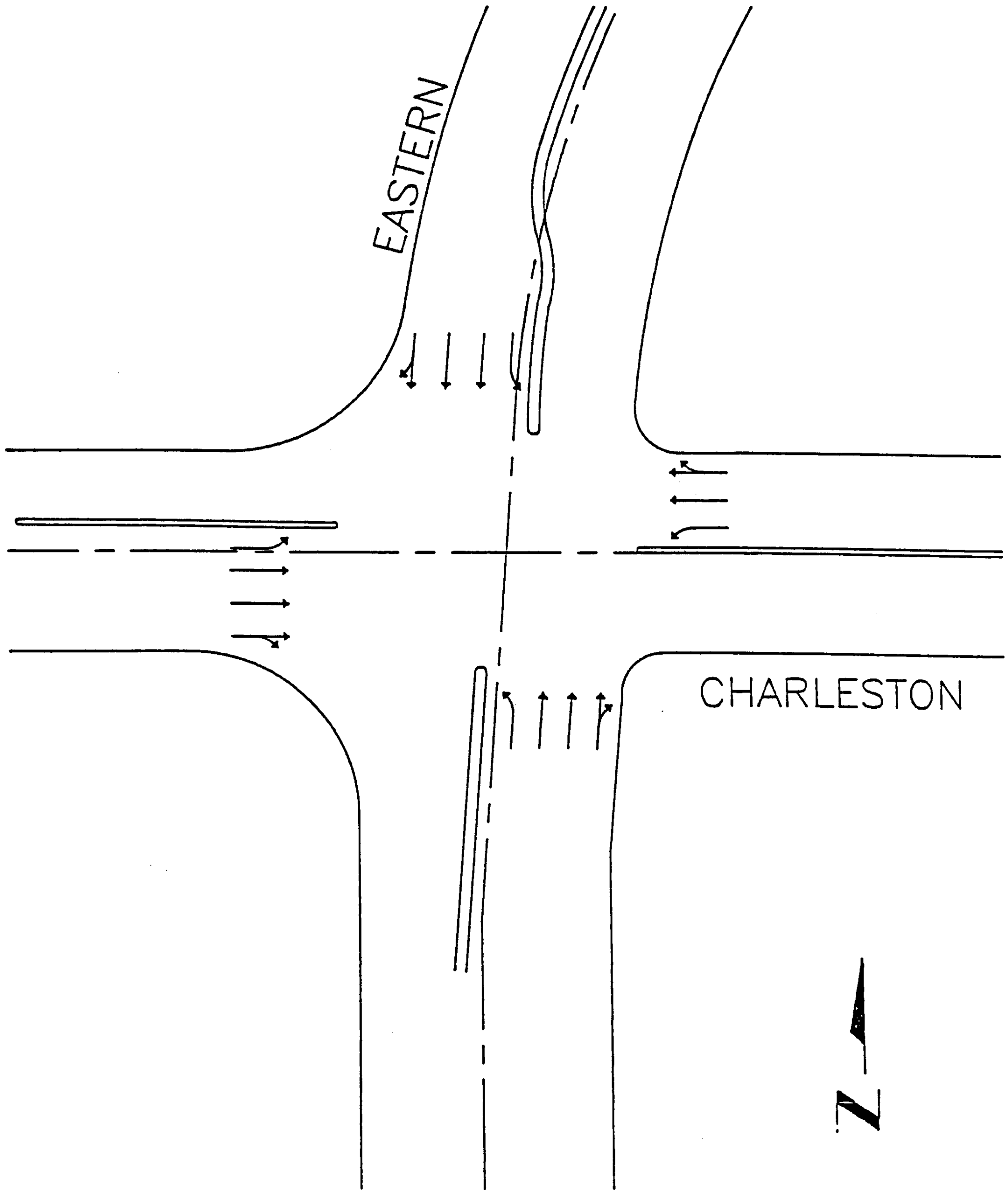
EPA. 1992. Guideline for Modeling Carbon Monoxide From Roadway Intersections. EPA-4454/R-92-05, U.S. EPA OAQPS, Research Triangle Park, NC. November 1992.

EPA. 1995. User's Guide to CAL3QHC Version 2.0: A Modeling Methodology for Predicting Pollutant Concentrations Near Roadway Intersections. EPA-454/R-92-06 (revised), U.S. EPA OAQPS, Research Triangle Park, NC. September 1995.

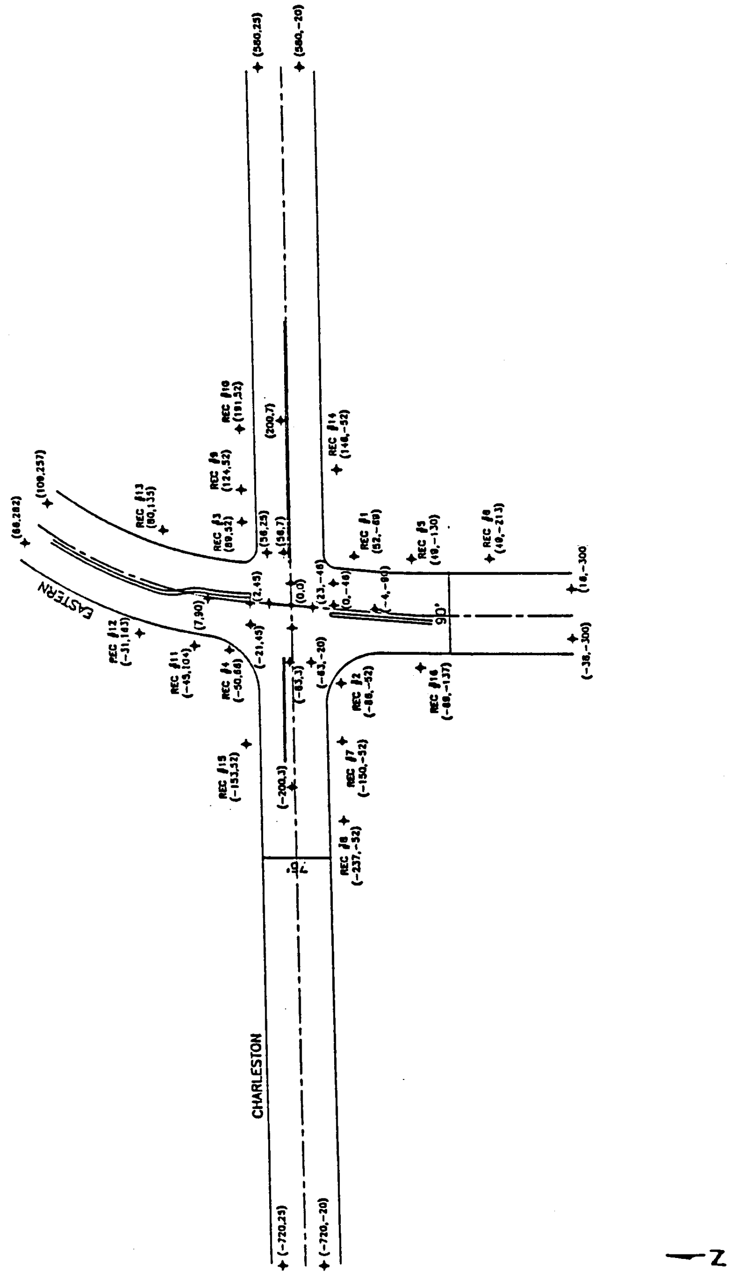
ENVIRON. 1998. Results of revised Phase II Base Case CO modeling, and recommendation of episode selection for future year assessments. Memorandum from ENVIRON, October 27, 1998

Appendix A

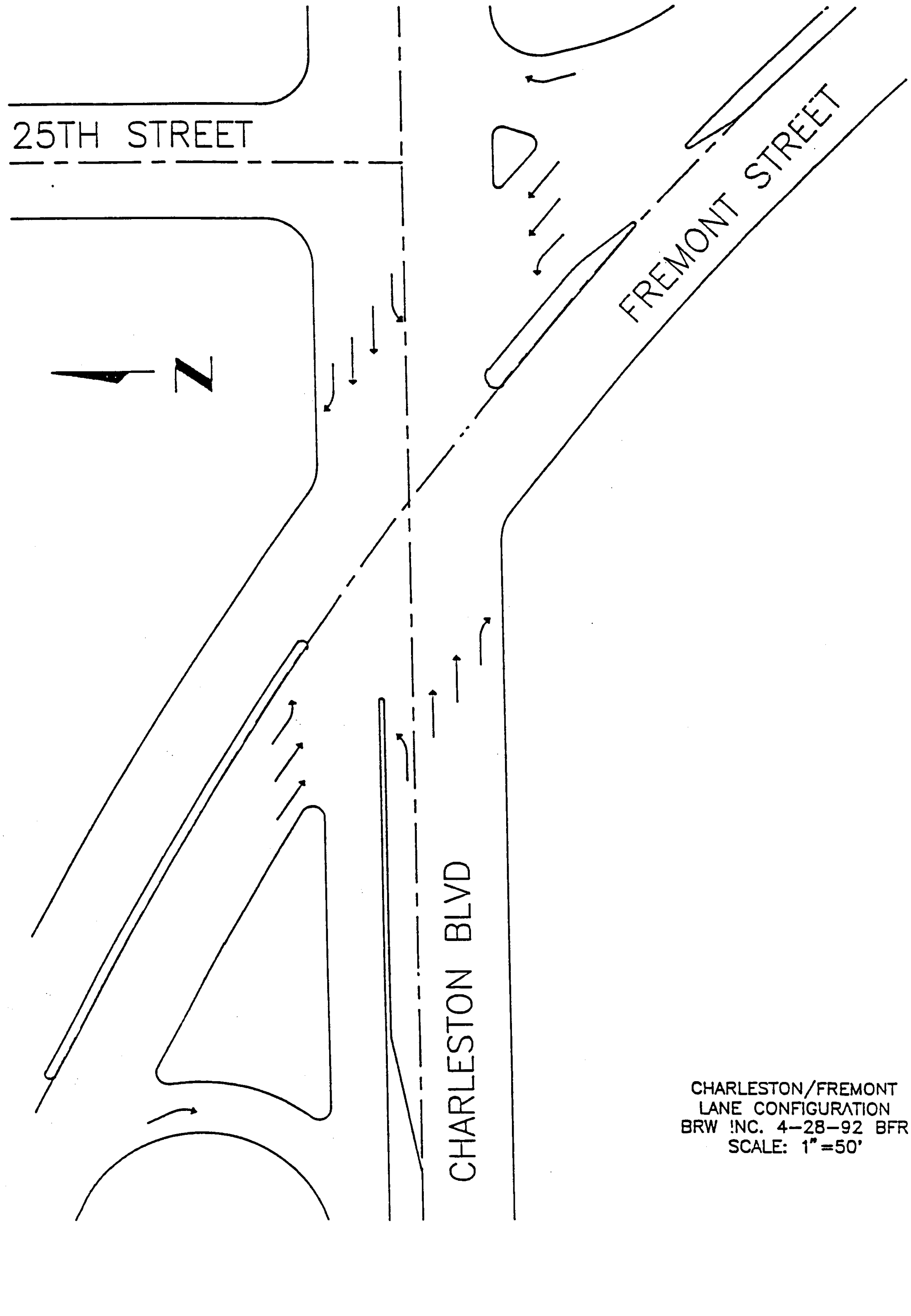
Cross-section and link coordinate/receptor diagrams for the three modeled intersections

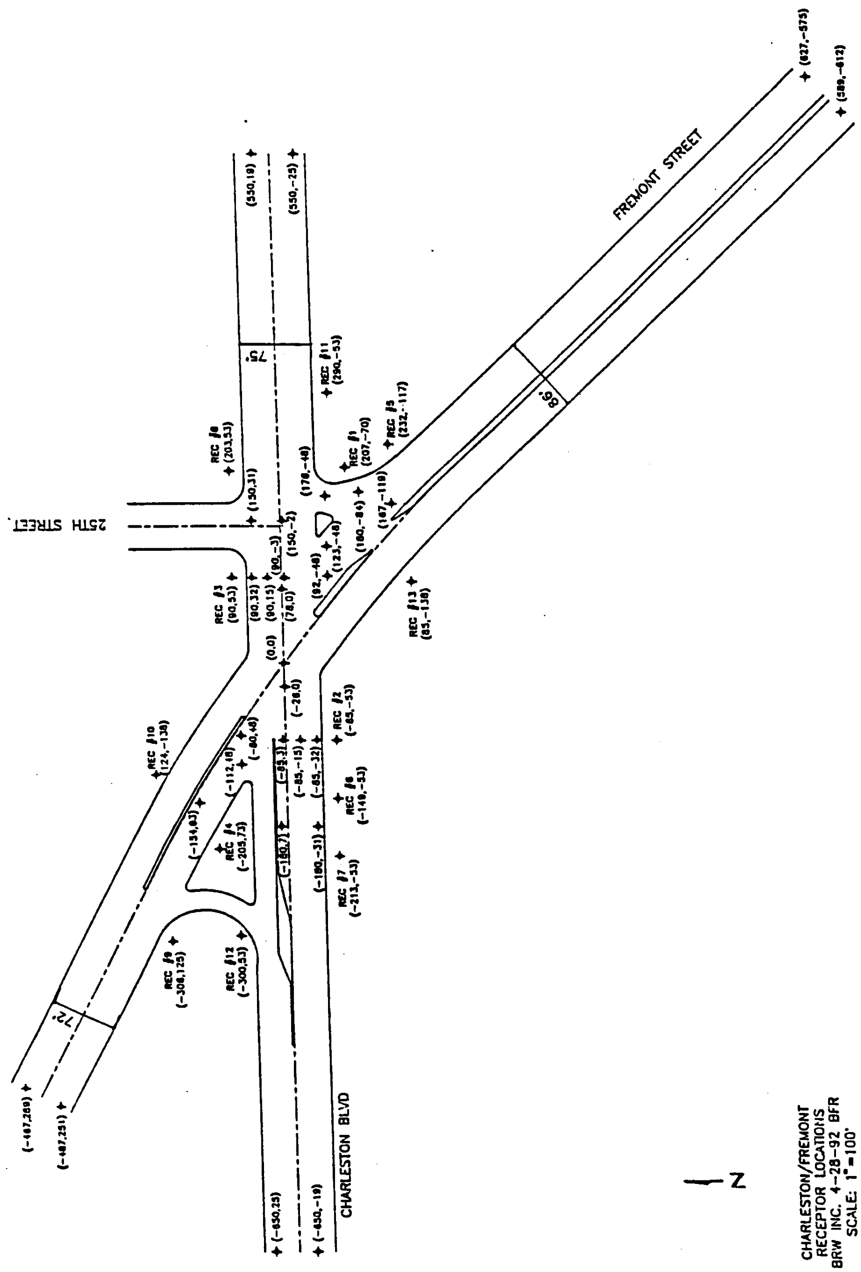


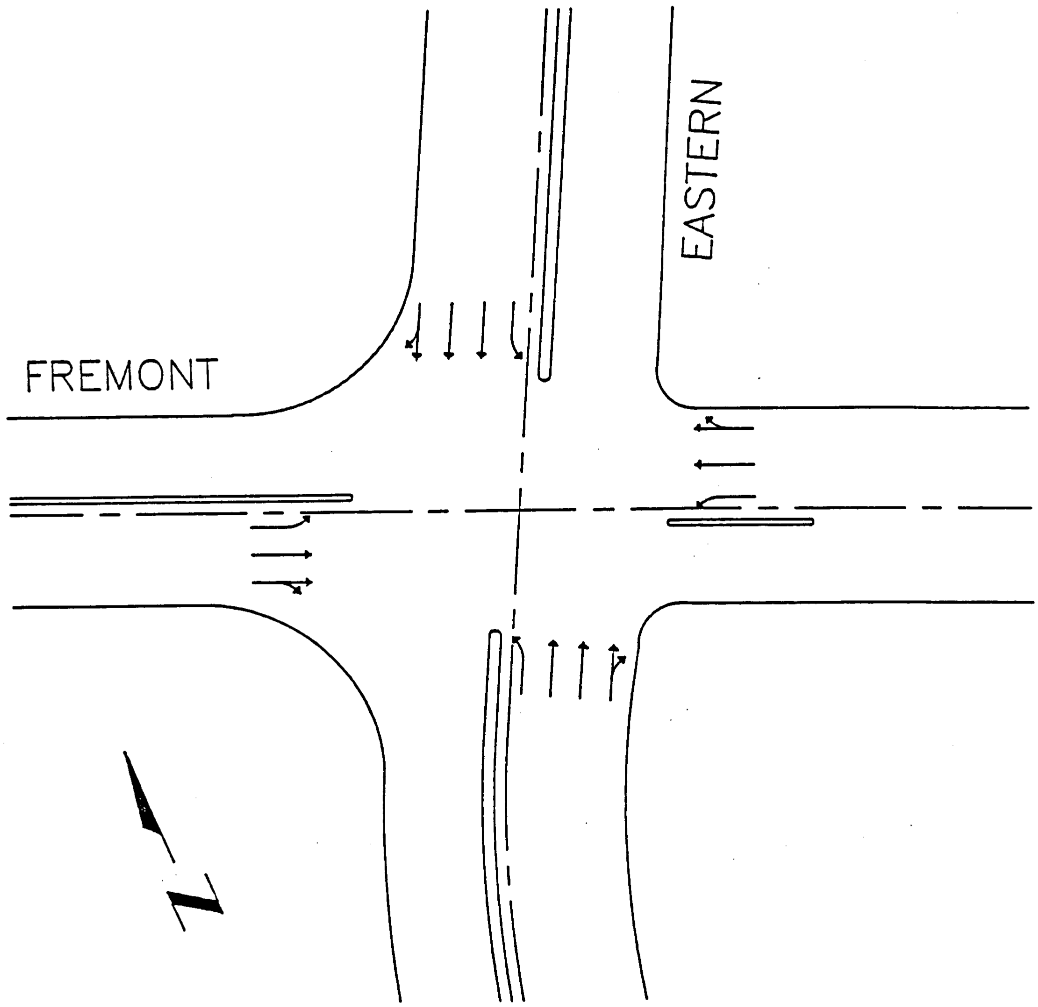
CHARLESTON/EASTERN
LANE CONFIGURATION
BRW INC. 4-28-92 BFR
SCALE: 1"=50'



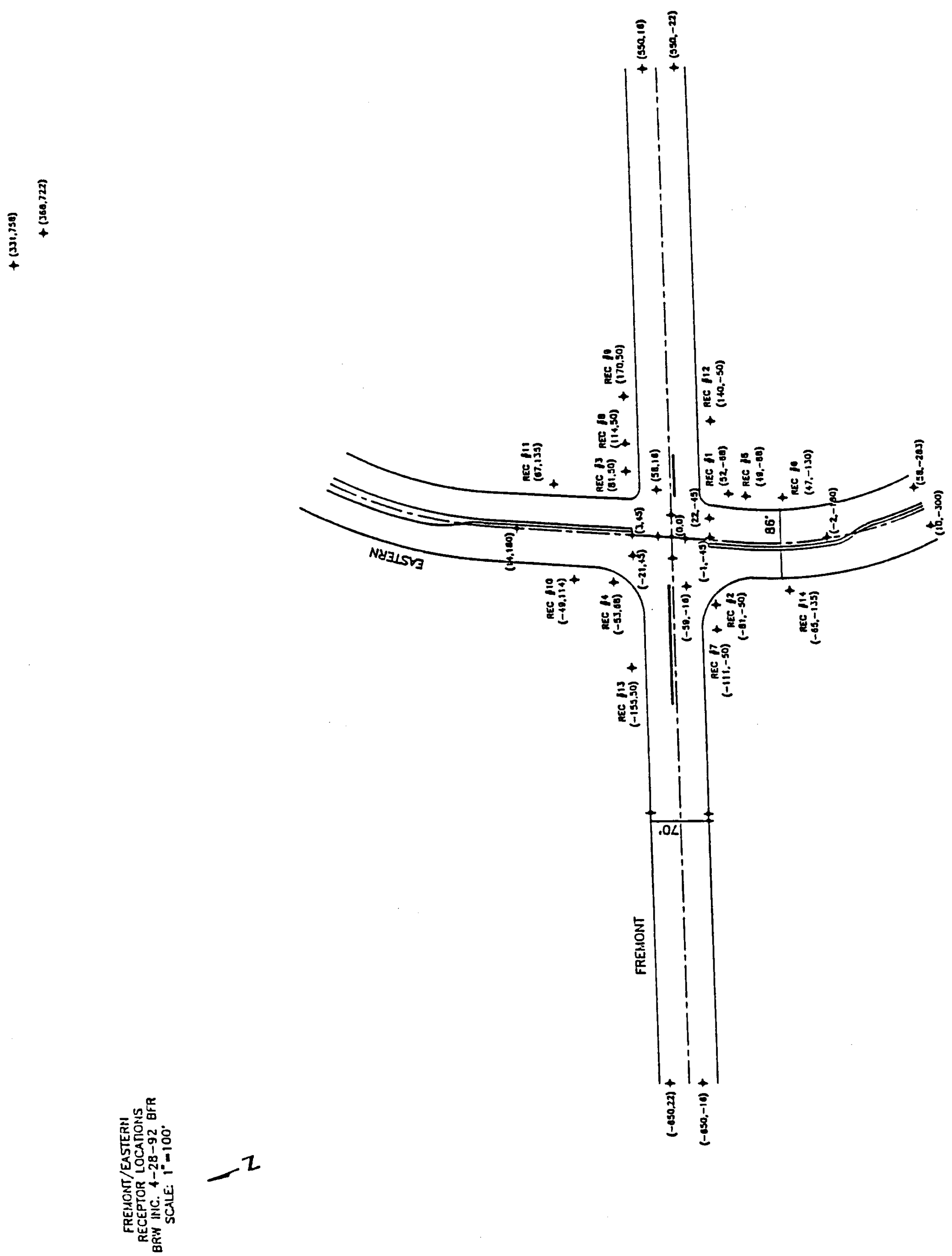
CHARLESTON/EASTERN
RECEPTOR LOCATIONS
BRW INC. 4-28-92 BFR
SCALE: 1"=100'


25TH STREET
FREMONT STREET
CHARLESTON BLVD
N
CHARLESTON/FREMONT
LANE CONFIGURATION
BRW INC. 4-28-92 BFR
SCALE: 1"=50'


FREMONT STREET
25TH STREET
CHARLESTON BLVD
N
CHARLESTON/FREMONT
RECEPTOR LOCATIONS
BRW INC. 4-28-92 BFR
SCALE: 1"=100'



FREMONT/EASTERN
LANE CONFIGURATION
BRW INC. 4-28-92 BFR
SCALE: 1"=50'


FREMONT/EASTERN
RECEPTOR LOCATIONS
BRW INC. 4-28-92 BFR
SCALE: 1"=100'
FREMONT
EASTERN
70'
86'

Appendix B

Hourly Turn Movement Traffic Volumes
2000 Primary Control Scenario

2000 Primary Control Hourly Turn Movement Volumes
Intersection of Eastern at Charleston

Hour	Southbound (from North)					Northbound (from South)					Westbound (from East)					Eastbound (from West)				
Ending	Left	Throu	Rights	App.	Dept.	Left	Throu	Rights	App.	Dept.	Left	Throu	Rights	App.	Dept.	Left	Throu	Rights	App.	Dept.
1	1	86	12	99	153	51	151	8	210	181	24	115	1	140	178	29	169	44	242	178
2	1	82	12	94	121	35	105	7	147	123	13	64	0	78	110	18	103	26	146	111
3	1	90	12	103	118	27	82	8	119	98	8	38	0	46	78	14	82	21	118	92
4	2	180	25	207	205	16	49	16	82	60	9	44	0	52	85	11	61	15	88	80
5	6	501	70	576	534	18	54	47	120	67	15	73	0	90	161	12	67	18	95	119
6	14	1234	170	1418	1296	39	115	115	270	132	41	199	1	242	408	14	85	21	120	213
7	14	1261	174	1450	1433	103	308	118	528	351	112	546	4	661	823	40	231	60	331	363
8	13	1110	153	1276	1472	191	572	104	865	662	236	1144	7	1387	1489	84	490	126	700	606
9	13	1121	154	1288	1523	214	645	105	964	763	238	1153	7	1398	1523	110	642	165	917	759
10	11	950	131	1093	1375	230	691	88	1010	847	199	966	6	1171	1327	151	879	226	1256	978
11	15	1321	183	1518	1780	239	717	123	1077	900	190	920	6	1116	1342	179	1047	269	1494	1184
12	16	1471	203	1691	1966	259	779	137	1175	986	191	928	6	1124	1391	202	1177	303	1683	1332
13	47	1276	233	1557	1741	107	892	181	1180	1150	200	964	12	1176	1305	247	1253	265	1764	1480
14	52	1402	257	1711	1855	123	1019	199	1341	1263	203	979	12	1195	1359	232	1179	249	1661	1430
15	48	1331	243	1622	1810	140	1167	189	1496	1426	217	1045	13	1275	1428	246	1249	264	1760	1487
16	45	1217	223	1485	1696	150	1242	173	1564	1514	199	962	12	1174	1334	260	1322	279	1862	1540
17	33	897	164	1095	1404	163	1349	127	1639	1641	207	999	12	1219	1326	279	1414	299	1993	1575
18	25	669	123	817	1134	171	1417	95	1682	1709	160	774	9	945	1068	284	1438	304	2025	1558
19	16	450	82	548	785	105	876	64	1044	1077	127	612	7	746	799	194	985	209	1387	1065
20	13	359	66	438	623	82	686	51	820	837	110	528	6	643	676	144	730	154	1028	794
21	11	302	55	369	510	68	569	42	680	693	80	387	5	471	510	120	608	128	856	661
22	8	219	40	268	372	57	473	31	561	566	58	276	4	337	374	90	456	97	642	495
23	6	161	29	197	275	37	308	22	367	376	42	202	2	246	269	67	338	72	476	368
24	4	107	20	130	193	28	236	15	278	283	39	186	2	227	235	45	229	48	322	247
Total	416	17800	2833	21049	24375	2653	14501	2067	19220	17707	2919	14104	133	17161	19596	3072	16235	3663	22966	18717

2000 Primary Control Hourly Turn Movement Volumes
Intersection of Fremont at Charleston

Hour	Southbound (from North)					Northbound (from South)					Westbound (from East)					Eastbound (from West)				
Ending	Left	Throu	Rights	App.	Dept.	Left	Throu	Rights	App.	Dept.	Left	Throu	Rights	App.	Dept.	Left	Throu	Rights	App.	Dept.
1	42	191	2	236	252	106	147	4	257	163	8	138	9	156	246	6	154	54	216	202
2	28	128	1	159	171	64	88	2	154	99	5	86	6	97	152	5	106	37	147	138
3	27	124	1	153	159	59	81	2	144	90	4	67	5	75	127	4	90	31	125	120
4	20	87	1	108	108	52	72	2	125	78	4	53	4	60	106	2	52	18	72	73
5	15	70	1	86	94	46	64	1	110	72	5	92	6	103	138	2	55	19	77	72
6	20	91	1	112	133	78	107	2	186	125	12	203	14	229	282	4	91	32	126	113
7	40	183	2	226	288	173	240	4	417	286	31	554	38	622	728	9	212	74	295	257
8	71	319	4	395	515	338	470	7	816	559	60	1061	72	1192	1404	16	392	136	544	470
9	86	387	5	477	639	326	454	8	787	546	58	1030	70	1157	1360	24	560	194	778	654
10	103	462	6	570	771	291	405	9	707	500	53	951	64	1068	1248	31	735	256	1021	847
11	103	464	6	573	808	337	468	9	814	561	48	853	58	958	1195	35	854	297	1187	968
12	119	536	7	662	920	361	501	12	873	607	54	973	66	1094	1341	40	950	330	1320	1081
13	164	529	4	697	1164	240	622	18	880	697	167	883	67	1117	1126	7	942	468	1417	1124
14	166	539	4	708	1150	246	640	19	905	715	172	909	70	1150	1159	7	885	440	1331	1070
15	152	493	4	649	1137	246	639	16	903	715	171	902	68	1141	1151	7	953	474	1434	1123
16	172	559	4	734	1240	236	609	19	864	687	173	911	70	1154	1150	8	1025	509	1542	1216
17	178	577	4	759	1302	243	628	20	891	701	160	844	64	1068	1090	8	1140	566	1714	1338
18	211	684	5	899	1407	209	542	24	774	608	143	748	57	948	962	8	1171	581	1761	1406
19	130	420	2	553	907	180	467	14	661	520	118	622	47	787	805	6	745	369	1120	889
20	95	308	2	405	682	145	377	11	533	421	100	526	40	666	673	5	554	275	832	660
21	98	315	2	415	649	147	381	11	539	420	86	454	34	574	602	4	499	247	751	607
22	81	263	1	345	500	113	295	9	416	321	59	310	24	394	425	2	358	178	539	449
23	84	269	2	354	450	92	237	9	338	259	51	265	20	336	358	2	263	131	396	356
24	61	199	1	263	330	84	216	7	306	232	37	194	15	245	278	1	189	94	284	257
Total	2266	8194	72	10540	15780	4412	8751	240	13401	9980	1777	13629	985	16389	18107	244	12976	5808	19025	15490

2000 Primary Control Hourly Turn Movement Volumes
Intersection of Eastern at Fremont

Hour		Southbound (from North)					Northbound (from South)					Westbound (from East)					Eastbound (from West)			
Ending	Left	Throu	Rights	App.	Dept.	Left	Throu	Rights	App.	Dept.	Left	Throu	Rights	App.	Dept.	Left	Throu	Rights	App.	Dept.
1	13	132	5	151	161	34	205	1	240	264	4	151	29	184	189	29	194	25	250	210
2	9	94	4	107	114	16	101	1	120	144	2	100	20	121	120	22	144	19	184	154
3	9	91	4	104	108	15	91	1	106	126	2	87	16	106	105	19	124	16	159	134
4	8	75	2	86	91	11	65	1	77	94	1	71	14	87	85	15	100	13	130	110
5	8	78	2	88	91	11	62	1	74	90	2	73	14	88	86	13	85	11	110	94
6	26	247	8	282	263	20	123	2	145	159	2	108	21	132	137	15	100	13	130	128
7	67	661	22	752	689	49	301	7	357	375	6	246	48	301	319	27	172	22	222	247
8	117	1142	39	1298	1186	88	535	13	635	659	11	436	85	532	562	39	255	33	326	384
9	100	985	33	1120	1037	105	634	11	751	758	9	371	72	453	509	51	332	42	425	444
10	98	952	33	1082	1011	108	655	11	774	787	9	369	72	450	510	60	391	51	501	500
11	91	885	31	1006	951	117	711	11	838	860	11	428	84	522	575	66	428	54	548	528
12	91	887	31	1009	959	123	745	11	877	899	11	415	81	507	568	73	475	61	609	576
13	177	882	44	1102	735	94	797	6	897	976	16	402	118	536	540	61	475	73	608	656
14	197	984	49	1229	1076	108	917	6	1031	1108	18	436	127	581	593	62	486	74	622	688
15	190	951	47	1188	1042	127	1082	6	1216	1272	18	438	128	585	614	61	475	73	608	671
16	217	1083	54	1354	1175	119	1008	7	1134	1204	19	458	134	610	632	62	483	74	619	706
17	199	997	49	1247	1111	143	1210	6	1359	1418	18	430	126	574	623	81	633	98	811	838
18	193	969	48	1210	1076	154	1308	6	1468	1496	15	376	111	501	579	78	605	93	774	780
19	151	752	38	939	819	112	945	5	1062	1072	11	273	80	364	422	47	367	57	470	522
20	120	603	31	754	660	87	742	4	833	857	11	260	77	346	378	39	303	47	389	428
21	95	475	24	594	530	67	569	4	640	689	12	280	82	375	372	37	288	45	369	385
22	81	409	20	511	458	64	535	2	601	634	8	220	65	293	304	34	263	40	313	348
23	65	323	16	403	370	44	367	2	411	457	8	196	58	262	256	33	262	40	335	328
24	38	191	9	239	231	32	270	1	303	346	7	163	48	217	204	28	219	34	280	258
Total	2361	14850	643	17856	15947	1849	13978	125	15950	16745	231	6790	1712	8727	9282	1055	7657	1109	9793	10119

Appendix C

CAL3QHC + UAM CO Concentrations for 2000 Primary Control Scenario

December 8 - 9, 1996 Episode

Predicted CO Concentrations (ppm) for 2000 Primary Control Case

December 8 - 9, 1996 Episode
Eastern/Charleston Intersection

Hour Beginning	UAM 1-hour	UAM 8-hour	CAL3QHC 1-hour	CAL3QHC 8-hour	UAM + CAL3QHC 1-hour	UAM + CAL3QHC 8-hour
15	0.40	4.20	3.70	3.59	4.10	7.78
16	1.11	4.85	3.40	3.56	4.51	8.41
17	2.21	5.40	3.60	3.31	5.81	8.72
18	3.28	5.79	4.10	3.00	7.38	8.79
19	5.48	5.93	4.00	2.55	9.48	8.48
20	7.33	5.70	4.50	2.11	11.83	7.82
21	7.36	5.19	2.50	1.75	9.86	6.94
22	6.39	4.65	2.90	1.70	9.29	6.35
23	5.64	4.32	3.50	1.85	9.14	6.17
0	5.53	4.29	1.40	1.99	6.93	6.28
1	5.31	4.46	1.10	2.31	6.41	6.78
2	4.41	4.57	0.50	2.74	4.91	7.31
3	3.65	4.35	0.50	3.14	4.15	7.48
4	3.19		1.60		4.79	
5	3.05		2.10		5.15	
6	3.81		4.10		7.91	
7	5.35		4.60		9.95	
8	6.94		4.00		10.94	
9	6.16		4.50		10.66	
10	2.63		3.70		6.33	
Maximum	7.36	5.93	4.60	3.59	11.83	8.79

Predicted CO Concentrations (ppm) for 2000 Primary Control Case

December 8 - 9, 1996 Episode
Fremont/Charleston Intersection

Hour Beginning	UAM 1-hour	UAM 8-hour	CAL3QHC 1-hour	CAL3QHC 8-hour	UAM + CAL3QHC 1-hour	UAM + CAL3QHC 8-hour
15	0.40	4.20	2.60	1.93	3.00	6.12
16	1.11	4.85	2.20	1.69	3.31	6.54
17	2.21	5.40	3.00	1.45	5.21	6.85
18	3.28	5.79	2.00	1.11	5.28	6.90
19	5.48	5.93	1.70	0.88	7.18	6.81
20	7.33	5.70	1.50	0.66	8.83	6.37
21	7.36	5.19	1.80	0.49	9.16	5.67
22	6.39	4.65	0.60	0.29	6.99	4.93
23	5.64	4.32	0.70	0.31	6.34	4.64
0	5.53	4.29	0.30	0.50	5.83	4.79
1	5.31	4.46	0.30	0.69	5.61	5.15
2	4.41	4.57	0.10	1.05	4.51	5.62
3	3.65	4.35	0.00	1.33	3.65	5.67
4	3.19		0.10		3.29	
5	3.05		0.20		3.25	
6	3.81		0.80		4.61	
7	5.35		2.20		7.55	
8	6.94		1.80		8.74	
9	6.16		3.20		9.36	
10	2.63		2.30		4.93	
Maximum	7.36	5.93	3.20	1.93	9.36	6.90

Predicted CO Concentrations (ppm) for 2000 Primary Control Case

December 8 - 9, 1996 Episode
Eastern/Fremont Intersection

Hour Beginning	UAM 1-hour	UAM 8-hour	CAL3QHC 1-hour	CAL3QHC 8-hour	UAM + CAL3QHC 1-hour	UAM + CAL3QHC 8-hour
15	0.40	4.20	2.80	2.74	3.20	6.93
16	1.11	4.85	3.30	2.49	4.41	7.34
17	2.21	5.40	3.20	2.21	5.41	7.62
18	3.28	5.79	3.00	1.86	6.28	7.65
19	5.48	5.93	2.60	1.55	8.08	7.48
20	7.33	5.70	3.10	1.29	10.43	6.99
21	7.36	5.19	2.40	0.95	9.76	6.14
22	6.39	4.65	1.50	0.73	7.89	5.37
23	5.64	4.32	0.80	0.80	6.44	5.12
0	5.53	4.29	1.10	1.08	6.63	5.36
1	5.31	4.46	0.40	1.28	5.71	5.74
2	4.41	4.57	0.50	1.63	4.91	6.19
3	3.65	4.35	0.50	2.00	4.15	6.35
4	3.19		0.40		3.59	
5	3.05		0.60		3.65	
6	3.81		2.10		5.91	
7	5.35		3.00		8.35	
8	6.94		2.70		9.64	
9	6.16		3.20		9.36	
10	2.63		3.50		6.13	
Maximum	7.36	5.93	3.50	2.74	10.43	7.65

APPENDIX C

Section Six
Carbon Monoxide Dispersion Modeling Protocol, Airport Related Pollutant Emissions, Clark County Airport Systems
(Airport 1)

Carbon Monoxide Dispersion Modeling Protocol
Airport Related Pollutant Emissions
Clark County Airport System

1. BACKGROUND

The Clark County Department of Comprehensive Planning is in the process of demonstrating attainment of the National Ambient Air Quality Standards (NAAQS) for carbon monoxide (CO) as part of a revised State Implementation Plan (SIP) for the Las Vegas Valley. The SIP is to be completed in 1999 and will be based on modeling results using the Urban Airshed Model (UAM) for a particular exceedance episode that occurred in December 1996.

Preliminary air quality modeling results show that on-road motor vehicles are the dominant source of CO emissions in the Valley and that adoption of certain controls on mobile sources, specifically automobiles, should result in successful attainment of the federal 8-hour CO standard (9 parts per million) by the year 2000. However, there is some uncertainty regarding emissions from certain other mobile sources. Some of these sources contribute a minor fraction to the total CO emissions in the Las Vegas Valley and operate outside nighttime and early morning periods associated with the highest ambient CO concentration. However, it is postulated that contributions from airport sources can be better represented than they are currently in the UAM. The complexity of airport sources combined with the fact that airport-related emissions are usually confined to a relative small area make them difficult to model in a grid-based model like the UAM. The fine scale emissions distributions at such facilities requires the use of a "micro-scale" modeling approach, such as would be used to model emissions associated with a high volume traffic intersection, where CAL3QHC is used as a supplement to the UAM. For this reason, the County has decided to evaluate airport emissions associated with the primary County owned and operated airports using the U.S. Air Force/Federal Aviation Administration Emissions and Dispersion Modeling System (EDMS). The EDMS was developed specifically for airport emissions analyses and is approved by the U.S. Environmental Protection Agency (EPA).

2. THE EMISSIONS AND DISPERSION MODELING SYSTEM (EDMS)

EDMS is a combined emissions and dispersion model for assessing air quality at civilian and military air bases. The model was developed by the Federal Aviation Administration (FAA) in cooperation with the United States Air Force (USAF). The primary applications of the model are generating an inventory of emissions caused by sources on and around an airport or air base and calculating pollutant concentrations in the surrounding environment.

The back-end for both the emissions inventory and dispersion modeling components of EDMS is a comprehensive database comprised of tables for system data and user-created sources and results. System data tables include emissions factors for civilian and military aircraft, civilian ground support equipment, civilian motor vehicles. Civilian motor vehicle emissions factors were generated by MOBILE5a for vehicle fleets between 1997 and the year 2020.

The emissions inventory module incorporates EPA-approved methodologies for calculating aircraft emissions, on- and off-road vehicle emissions, and stationary source emissions. The dispersion modeling module incorporates the PAL 2 and CALINE 3 dispersion models—both EPA validated for the various sources of emissions. Both the inventory and dispersion modeling modules interact with the system database to retrieve and store data.

EDMS performs dispersion analyses by incorporating previously developed dispersion models. These earlier models have many known assumptions and limitations regarding their application. Assumptions used in the dispersion analysis module include: a simple or relatively flat terrain, conservation of mass (i.e., negligible chemical breakdown of original substance), and steady state atmospheric conditions over the averaging period of one hour. Additionally, Gaussian dispersion algorithms used by EDMS are limited to transport distances of less than 50 kilometers and do not consider complex aerodynamic effects such as downwash from buildings. Pollutants currently included in EDMS for dispersion analyses are carbon monoxide (CO), oxides of nitrogen (Nox), oxides of sulfur (SOx), and particulate matter less than 10 microns in diameter (PM-10).

3. SOURCES OF EMISSIONS AT AIRPORTS

At airports, a variety of sources are responsible for air pollution emissions. The predominant sources of carbon monoxide emissions are aircraft and ground access vehicles, including passenger automobiles, courtesy vehicles, taxicabs, rental cars, and buses. Other sources include aircraft service vehicles and ground support equipment, fuel storage facilities, boilers, incinerators, and generators. Airport construction and painting projects can be temporary sources of CO emissions. The methodology that would be used to model these sources of CO emissions is described in Section IV.

4. METHODOLOGY FOR THE DISPERSION OF AIRPORT RELATED POLLUTANT EMISSIONS

The following sections describe the methodology that would be employed to: (1) conduct the air quality dispersion analyses for McCarran International Airport, North Las Vegas Airport, and Henderson Executive Airport and (2) incorporate the results of the EDMS dispersion analyses into the Urban Airshed Model (UAM).

4.1 ANNUAL EMISSIONS INVENTORY

The first component of the air quality dispersion analyses would be calculating annual airport-related emissions of carbon monoxide associated with activity at McCarran International Airport, North Las Vegas Airport, and Henderson Executive Airport. Annual emissions inventories would be calculated for 1996, 2000, 2010, and 2020. While much of the data necessary to compute 1996 carbon monoxide emissions is documented in the report *Air Pollutant Emissions Inventory, McCarran International, North Las Vegas, and Henderson Executive Airports* (Air Pollutant Emissions Inventory) prepared by Leigh Fisher Associates, additional analyses would be required to match specific conditions that were in place during the December 9-10, 1996 CO exceedance episode. Specific data required to compute annual airport-related CO emissions and assumptions that would be incorporated into the emissions modeling are described in detail below.

4.1.1 Aircraft Emissions

Annual aircraft emissions are a function of the number of annual aircraft operations, expressed as landing and takeoff (LTO) cycles, the aircraft fleet mix (types of aircraft used), and the length of time the aircraft spend taxiing and idling on the ground. The EDMS database contains an expansive list of aircraft types (airframes) and engine types for use in air quality analyses. Emissions associated with individual aircraft are a function of the mode the aircraft operating mode (i.e. taxiing/idling, takeoff, etc.), the type of aircraft engine that is attached to the airframe, and emissions factors associated with that particular engine type and operating mode.

Aircraft activity and fleet mix assumptions for McCarran International Airport for 1996 would be based on: (1) airline operations summaries provided by the Clark County Department of Aviation, (2) FAA operations data, (3) data contained in the Air Pollutant Emissions Inventory, and (4) airline schedule information obtained from Back Information Services. Future year aircraft activity and fleet mix information would be based on aircraft activity forecasts developed specifically for the dispersion analysis.

For North Las Vegas Airport and Henderson Executive Airport the number of LTO cycles in 1996 would be derived from FAA control tower summaries. Future year activity data would be based on forecasts of aviation activity prepared specifically for the dispersion analysis consistent with regional population and employment growth projections used for the UAM analyses. The existing and future aircraft fleet mix at North Las Vegas Airport would be based on assumptions contained in the *report Final Environmental Assessment, Proposed Runway 12L-30R, North Las Vegas Airport*. The existing and future aircraft fleet mix at Henderson Executive Airport would be based on information contained in the report, *Final Environmental Assessment, Master Plan Report Recommendations, Henderson Executive Airport*, prepared by Leigh Fisher Associates.

Average aircraft taxi/idle times in 1996, 2000, 2010, and 2020 would be based on an analysis of taxi distances at each of the Airports, and in the case of McCarran International Airport, on a review of data from the FAA's Consolidated Operations and Delay Analysis System (CODAS). It should be noted that the EDMS incorporates default operating times for the taxi in and out modes of operation for each aircraft type contained in the model database. For situations where taxi/idle times specific to Clark County airports are indeterminable, default values contained in the EDMS would be used to model aircraft taxiing characteristics.

4.1.2 Ground Service Equipment

Ground service equipment includes a wide range of vehicles that service aircraft. Examples of GSE include tugs that haul baggage cars and other equipment, fuel trucks, catering trucks and other service vehicles, and ground power units (GPUs) that provide electrical power to aircraft when they are parked. The majority of GSE are powered by gasoline, diesel, or propane and most emit CO, hydrocarbons (HC), and oxides of nitrogen (NOx). Emissions from GSE are a function of fuel consumption. Factors that influence the level of emissions from GSE include airport activity levels, the type and size of the GSE, and the airport layout.

By default, the EDMS assigns a fleet of GSE to each aircraft type included in the study. Specifications regarding model default GSE (i.e., type of fuel used, operating time in mode, etc.) are summarized in Table 1 below.

Table 1: Assumed GSE Usage by Aircraft Category

Aircraft Category	Assumed GSE and APU	Default Operating Time (Min/LTO cycle)
Commuter	APU GTCP 36 (80 HP)	26
	Diesel Aircraft Tug Narrow	6
	Diesel Belt Loader	48
	Diesel Cabin Service	15
	Diesel Food Truck	35
	Diesel Fuel Truck	35
	Diesel Lavatory Truck	20
	Gasoline Baggage Tug	85
Narrow-body	APU GTCP 85 (200 HP)	26
	Diesel Aircraft Tug Narrow	6
	Diesel Belt Loader	48
	Diesel Cabin Service	15
	Diesel Food Truck	35
	Diesel Fuel Truck	35
	Diesel Lavatory Truck	20
	Gasoline Baggage Tug	85
Wide-body	APU GTCP 660 (300 HP)	26
	Diesel Aircraft Tug Wide	8
	Diesel Airstart Transporter	3
	Diesel Airstart Unit	3
	Diesel Belt Loader	48
	Diesel Cabin Service	15
	Diesel Container Loader	92
	Diesel Food Truck	35
	Diesel Fuel Truck	35
	Diesel Lavatory Truck	20
	Diesel Transporter	10
	Diesel Water Truck	12
	Gasoline Baggage Tug	85

GSE= Ground Service Equipment
APU = Aircraft Power Unit
LTO Cycle = Landing Takeoff Cycle

Source: Emissions and Dispersion Modeling System.
Prepared by: Ricondo & Associates, Inc.

In 1996 the Clark County Department of Aviation completed an inventory of GSE equipment used by each airline company and ground service provider at McCarran International Airport. GSE assignments at McCarran International Airport in 1996 and for future years 2000, 2010, and 2020 would be determined through a comparison of the results of the 1996 inventory and model defaults. GSE emissions at North Las Vegas Airport and Henderson Executive Airport would be based on EDMS defaults.

4.1.3 Ground Access vehicles (On-Road Motor Vehicles)

Ground access vehicle traffic on roadways and in airport parking lots and garages can be a significant source of CO emissions. The methodology that would be used to model ground access vehicle emissions for the three airports is described below.

- Traffic volumes on airport roadways and in County controlled parking lots at McCarran International Airport for 1996 would be based on traffic counts provided by the Clark County Department of Aviation. Future traffic volumes would be derived from the forecasts prepared for the dispersion analysis. Figure 1, which was prepared by Leigh Fisher Associates for the Air Pollutant Emissions Inventory, depicts terminal area roadway segments that would be modeled in the EDMS. Traffic movements on several additional roadway segments not depicted on Figure 1 (i.e. cargo truck traffic on Tamurus Street and trips made to general aviation facilities on the westside of the Airport), would be modeled in addition to these "on-airport" roadways.

- Ground access vehicle trips at North Las Vegas and Henderson Executive airports are a function of the number of general aviation and air tour operations that occur at the respective facilities. For these airports vehicle trips associated with general aviation tenants and commercial (air tour) tenants would be calculated for 1996 and future years 2000, 2010, and 2020 using methodologies developed in previous planning studies.

Mobile source emissions factors developed by the Regional Transportation Commission (RTC) for the Las Vegas Metro Area using the MOBILE5a model would be used in lieu of default factors for on road motor vehicles incorporated in the EDMS database to more accurately represent conditions in the Las Vegas metropolitan area. To account for temperature variations that occurred during the December 9-10, 1996 exceedance event, mobile source CO emissions factors would be computed using the MOBILE5a model for each hour of the 20-hour exceedance event.

Mobile source emissions factors developed by the RTC for the Las Vegas Metro Area assume a percentage of heavy duty diesel equipment in the vehicle fleet. Because airport parking areas are unlikely to accommodate heavy duty diesel vehicles, it is proposed that they be modeled using a different set of emissions factors. Parking lot emissions factors would be developed using the MOBILE5a model.

4.1.4 Point Source Emissions

Point sources of emissions at airports include power generating and heating plants, incinerators, fuel storage tanks, and surface coating facilities. Facilities owned and controlled by the Clark County Department of Aviation at the three airports would be modeled in EDMS. Information regarding the location and type of point source emitters at each of the three airports would be obtained from the Clark County Department of Aviation.

4.1.5 Airport-Related Construction Projects

Airport related construction activity planned at McCarran International Airport, North Las Vegas Airport, and Henderson Executive Airport will generate CO emissions. Emissions caused by truck traffic to and from the airports and by heavy duty diesel vehicles on construction sites would be accounted for in EDMS emissions inventory calculations.

4.2 AIR QUALITY DISPERSION ANALYSES

Dispersion modeling using EDMS is significantly more complex in scope and in data input requirements than emissions inventory modeling. Users must (1) specify coordinates for sources of pollutants, (2) assign aircraft to runways, runway queues, taxiways, and gate areas, (3) develop appropriate operational profiles for mobile sources, (4) develop weather variables for individual hours, and (5) define other source specific parameters for each emissions source included in the dispersion analysis. The user is also required to define individual receptors or grids of receptors for pollutant concentration estimation.

Several key assumptions that would be incorporated in the dispersion modeling aspect of the study are described in the following sections.

4.2.1 Coordinates of Pollutant Sources

Coordinates for major point, area (e.g., parking lots), and line sources of pollutant emissions would be derived from Airport Layout Plans maintained by the Clark County Department of Aviation.

4.2.2 Airport Operational Profiles

Operational profiles for aircraft, ground access vehicles, and ground support equipment would be defined on the basis of available data including airline schedules.

4.2.3 Meteorological Data

The EDMS uses five weather parameters in its dispersion modeling: temperature, wind speed, wind direction, Pasquill-Gifford Stability Classification, and mixing height. Meteorological data used in the dispersion modeling would include Hourly Surface Observations TD-3280 weather data from the National Climatic Data Center (NCDC) and weather data contained in the County's Urban Airshed Model (UAM) for the exceedance episode.

4.2.4 Grid Receptors

In the Urban Airshed Model, the Las Vegas Valley Basin is subdivided into 250 identical, one-kilometer grids cells (50x50 grid) for air pollutant concentration estimation. To accurately measure airport related CO concentrations, a more refined (smaller) grid of receptors would be defined for EDMS modeling. The set of grid receptors would subdivide and directly overlay the one kilometer grid cells modeled in the UAM. The distance between receptors and the overall extent of the receptor grid would be determined by running the UAM with and without existing airport related factors and comparing the results of the UAM CO concentration patterns.

4.3 ADD RESULTS OF EDMS MODELING TO UAM CONCENTRATIONS

EDMS dispersion predictions for the 1996 episode, and for future years would be added to "background" concentrations derived from the UAM (run without airport-related sources of emissions) to obtain total CO concentrations. EDMS receptors located within a given UAM 1-kilometer grid cell would be assigned that cell's background concentration. Total concentrations would be determined for the 1996 base case and future years 2000, 2010, and 2020.

5. PROPOSED SCOPE OF WORK

The proposed scope of services for the air quality dispersion analysis study is located in Appendix A of this document.

APPENDIX C

Section Seven
Dispersion Modeling of Carbon Monoxide Emissions, from Three Clark County Airports in Support of the Revised CO SIP
(Airport 1)

Final

DISPERSION MODELING OF CARBON MONOXIDE EMISSIONS FROM THREE CLARK COUNTY AIRPORTS IN SUPPORT OF THE REVISED CO SIP

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1. INTRODUCTION

BACKGROUND

The Clark County Department of Comprehensive Planning is in the process of demonstrating attainment of the National Ambient Air Quality Standards (NAAQS) for carbon monoxide (CO) as part of a revised State Implementation Plan (SIP) for the Las Vegas Valley. The SIP is to be completed in 1999 and will be based on modeling results using the Urban Airshed Model (UAM) for a particular exceedance episode that occurred in December 1996.

Preliminary air quality modeling results show that on-road motor vehicles are the dominant source of CO emissions in the Valley and that adoption of certain controls on mobile sources, specifically automobiles, should result in successful attainment of the federal 8-hour CO standard (9 parts per million) by the year 2000. However, there is some uncertainty regarding emissions from other types of mobile sources. Many other categories of mobile sources (e.g., lawn, garden, and industrial equipment, construction activity, etc.), contribute a minor fraction to the total CO emissions in the Las Vegas Valley, and/or operate outside nighttime and early morning periods associated with the highest ambient CO concentrations. Therefore, predictive model results should not be sensitive to emission uncertainties associated with these specific categories of mobile sources.

It has been postulated, however, that contributions from airport sources can be better represented, both in magnitude and timing/location, with models other than the UAM, leading to a more accurate representation of air quality in the vicinity of airports. The complexity of airport sources combined with the fact that airport-related emissions are usually confined to a relatively small areas make them difficult to model using a grid-based model like the UAM. The fine-scale emissions distribution at such facilities requires the use of a “micro-scale” modeling approach, such as would be used to model emissions associated with a high volume traffic intersection, where CAL3QHC is used as a supplement to the UAM. For this reason, the County has decided to evaluate airport emissions associated with the primary County owned and operated airports using the Emissions and Dispersion Modeling System (EDMS). The EDMS was developed specifically for airport emission analyses and is approved by the U.S. Environmental Protection Agency (EPA).

THE EMISSIONS AND DISPERSION MODELING SYSTEM (EDMS)

EDMS is a combined emissions and dispersion model for assessing air quality at civilian and military air bases. The model was developed by the Federal Aviation Administration (FAA) in cooperation with the United States Air Force (USAF). The primary aspects of the model include the development of an inventory of emissions generated by sources within and around an airport, and the calculation of pollutant concentrations in the surrounding environment.

The back-end for both the emissions inventory and dispersion modeling components of EDMS is a comprehensive database comprised of tables for system data, user-created sources, and results.

System data tables include emissions factors for civilian and military aircraft, ground support equipment, and motor vehicles. Both the inventory and dispersion modules interact with the system database to retrieve and store data.

The emissions inventory module incorporates EPA-approved methodologies for calculating aircraft emissions, on- and off-road vehicle emissions, and stationary source emissions. For example, motor vehicle emission factors are generated by MOBILE5a.

EDMS performs dispersion analyses by incorporating previously developed dispersion models (PAL2 and CALINE3-both EPA validated for the various sources of emissions). These earlier models have many known assumptions and limitations regarding their application. Assumptions used in the dispersion analysis module include: a simple or relatively flat terrain, conservation of mass (i.e., negligible chemical breakdown of original substance), and steady state atmospheric conditions over the averaging period of one hour. Additionally, Gaussian dispersion algorithms used by EDMS are limited to transport distances of less than 50 kilometers and do not consider complex aerodynamic effects such as downwash from buildings. Pollutants currently included in EDMS for dispersion analyses are carbon monoxide (CO), oxides of nitrogen (NOx), oxides of sulfur (SOx), and particulate matter less than 10 microns in diameter (PM-10).

At airports, a variety of sources generate air pollution emissions. The predominant sources of carbon monoxide emissions are aircraft and ground access vehicles, including passenger automobiles, courtesy vehicles, taxicabs, rental cars, and buses. Other sources include aircraft service vehicles and ground support equipment, fuel storage facilities, boilers, incinerators, and generators. Airport construction and painting projects can be temporary sources of CO emissions.

This report presents the results from modeling CO at three Clark County airports within the Las Vegas Valley using EDMS. The resulting concentrations from EDMS are added to UAM predicted "background" concentrations to provide a total CO concentration field for each scenario modeled, much the same way micro-scale intersection modeling is performed as described by EPA's CO modeling guidance (EPA, 1992). The total 8-hour average CO concentrations at the individual receptors are then rank-ordered to show the highest resulting concentrations, at which point an attainment/maintenance evaluation can be made. Section 2 briefly describes the configuration, setup, and application of EDMS. A more complete and detailed description of the methodology used to model the atmospheric dispersion of airport-related CO emissions is provided in the report *Carbon Monoxide Emissions Inventories and Dispersion Modeling, McCarran International, North Las Vegas, and Henderson Executive Airports* prepared by Ricondo & Associates (1999). Section 3 presents the EDMS/UAM results. A more complete description of the UAM CO modeling performed for the Las Vegas Valley is provided in *The Las Vegas Valley Carbon Monoxide Urban Airshed Model Update Project - Phase II: Modeling to Demonstrate Attainment of the Carbon Monoxide Standard* (Emery et al., 1999).

2. MODELING METHODOLOGY REVIEW

This section summarizes the methodology that was employed to: (1) conduct the air quality dispersion analyses for McCarran International Airport, North Las Vegas Airport, and

Henderson Executive Airport, and (2) add the results of the EDMS dispersion analyses to "background" CO fields developed using the UAM. A more detailed description is provided by Ricondo & Associates (1999).

ANNUAL EMISSIONS INVENTORY

The first component of the air quality dispersion analyses was the calculation of annual airport-related emissions of carbon monoxide associated with activity at McCarran International Airport, North Las Vegas Airport, and Henderson Executive Airport. Annual emissions inventories were calculated for the 1996 base year, the 2000 attainment year, and the 2010 and 2020 future years. While much of the data necessary to compute 1996 CO emissions are documented in the report *Air Pollutant Emissions Inventory, McCarran International, North Las Vegas, and Henderson Executive Airports* by Leigh Fisher Associates (1998a), additional analyses were required to match specific conditions that were in place during the December 8-9, 1996 CO exceedance episode. It was therefore necessary to review and update information and assumptions used to develop the original EDMS emission files, including: (1) CO emission factors used to model emissions from ground access vehicles to confirm their accuracy (appropriateness of fleet mix and operating modes assumed); and (2) ground traffic data obtained from the Department of Aviation. Specific data required to compute annual airport-related CO emissions, and assumptions that were incorporated into the emissions modeling, are described later in this section.

The total annual CO emissions (tons) by airport and modeling year, as estimated for these analyses, are given below:

	Year			
Airport	**1996**	**2000**	**2010**	**2020**
McCarran International	10,018	10,839	15,769	22,837
North Las Vegas	2,727	3,201	3,484	3,814
Henderson Executive	536	723	1,039	1,494

The emissions calculated in this effort for 1996 are significantly higher than the 1995 annual CO emissions used in the UAM modeling (Emery et al., 1999). The UAM 1995 annual airport emissions were based on projections from a 1990 inventory compiled by Clark County (BRW and SAI, 1992; Clark County, 1992). To illustrate this, the 1995 UAM estimate for McCarran was 4,960 tons/year (50% below the EDMS estimates); North Las Vegas was 973 tons/year (64% below EDMS); and Henderson was 252 tons/year (53% below EDMS).

Aircraft Emissions

Annual aircraft emissions are a function of the number of annual aircraft operations, expressed as landing and takeoff (LTO) cycles, the aircraft fleet mix (types of aircraft used), and the length of time aircraft spend taxiing and idling on the ground. The EDMS database contains an expansive list of aircraft types (airframes) and engine types for use in air quality analyses. Emissions associated with individual aircraft are a function of the aircraft operating mode (i.e. taxiing/idling, takeoff, etc.), the type of aircraft engine that is attached to the airframe, and emissions factors associated with that particular engine type and operating mode.

Aircraft activity and fleet mix assumptions for McCarran International Airport for 1996 were based on: (1) airline operations summaries provided by the Clark County Department of Aviation, (2) FAA operations data, and (3) data contained in the *Air Pollutant Emissions Inventory* by Leigh Fisher Associates (1998a). Future year aircraft activity and fleet mix information were based on aircraft activity forecasts developed specifically for the dispersion analysis.

For North Las Vegas and Henderson Executive Airports the number of LTO cycles in 1996 were derived from FAA Airport Traffic Control Tower (ATCT) summaries. Future year activity data were based on forecasts of aviation activity prepared specifically for the dispersion analysis. The existing and future aircraft fleet mixes at North Las Vegas Airport were based on assumptions contained in the report, *Final Environmental Assessment, Proposed Runway 12L-30R, North Las Vegas Airport*, prepared by Leigh Fisher Associates (May 1997). The existing and future aircraft fleet mix at Henderson Executive Airport were based on information contained in the report, *Final Environmental Assessment, Master Plan Report Recommendations, Henderson Executive Airport*, prepared by Leigh Fisher Associates (1998b).

Average aircraft taxi/idle times in 1996, 2000, 2010, and 2020 were based on an analysis of taxi distances at each of the airports, and in the case of McCarran International Airport, on a review of data from the FAA's Consolidated Operations and Delay Analysis System (CODAS). It should be noted that the EDMS incorporates default operating times for the taxi in and out modes of operation for each aircraft type contained in the model database. For situations where taxi/idle times specific to Clark County airports were indeterminable, default values contained in the EDMS were used to model aircraft taxiing characteristics.

Ground Service Equipment

Ground service equipment (GSE) includes a wide range of vehicles that service aircraft. Examples of GSE include tugs that haul baggage cars and other equipment, fuel trucks, catering trucks and other service vehicles, and ground power units (GPUs) that provide electrical power to aircraft when they are parked. The majority of GSE are powered by gasoline, diesel, or propane and most emit CO, hydrocarbons (HC), and oxides of nitrogen (NOx). Emissions from GSE are a function of fuel consumption. Factors that influence the level of emissions from GSE include airport activity levels, the type and size of the GSE, and the airport layout. By default, the EDMS assigns a fleet of GSE to each aircraft type included in the study.

In 1996 the Clark County Department of Aviation completed an inventory of GSE equipment used by each airline company and ground service providers at McCarran International Airport. GSE assignments at McCarran International Airport in 1996 and for future years 2000, 2010, and 2020 were determined through a comparison of the results of the 1996 inventory and model defaults. GSE assignments at North Las Vegas Airport and Henderson Executive Airport were based on information provided by the Clark County Department of Aviation.

Ground Access vehicles (On-Road Motor Vehicles)

Ground access vehicle traffic on roadways and in airport parking lots and garages can be a significant source of CO emissions. The methodology that was used to model ground access vehicle emissions for the three airports is described below:

- Traffic volumes on airport roadways and in County controlled parking lots at McCarran International Airport for 1996 were based on traffic counts provided by the Clark County Department of Aviation. Future traffic volumes were derived from the forecasts prepared for the dispersion analysis. Traffic movements on several additional roadway segments (i.e. cargo truck traffic on Spencer Street and trips made to general aviation facilities on the west side of the Airport), were modeled in addition to "terminal area" roadways.

- Ground access vehicle trips at North Las Vegas and Henderson Executive airports are a function of the number of general aviation and air tour operations that occur at the respective facilities. For these airports vehicle trips associated with general aviation tenants and commercial (air tour) tenants were calculated for 1996 and future years 2000, 2010, and 2020 using methodologies developed in previous planning studies.

MOBILE5b emissions factors, developed for the Clark County Department of Comprehensive Planning (Emery et al., 1999) for the Las Vegas Valley UAM applications, were used for on-road motor vehicles to more accurately represent conditions in the Las Vegas metropolitan area. To account for local temperatures that occurred during the December 8-9, 1996 exceedance event, mobile source CO emissions factors were computed using the MOBILE5b model for each hour of the 20-hour modeling period. These were used to derive scaling factors to adjust the annual average emission factors to the emission rates appropriate for the modeling episode.

Mobile source emissions factors developed by Clark County assume a percentage of heavy duty diesel equipment in the vehicle fleet. Because airport parking areas are unlikely to accommodate heavy duty diesel vehicles, this fraction was removed and the emission factors rescaled to reflect emissions from the remaining light-duty vehicle mix. These modified emission factors were applied to the parking areas only; all other ground access routes assumed the same vehicle fleet mix as used for the UAM applications.

Point Source Emissions

Point sources of emissions at airports include power generating and heating plants, incinerators, fuel storage tanks, and surface coating facilities. Facilities owned and controlled by the Clark County Department of Aviation at the three airports were modeled using the EDMS. Information regarding the location and type of point source emitters at each of the three airports were obtained from the Clark County Department of Aviation.

AIR QUALITY DISPERSION ANALYSES

Dispersion modeling using EDMS is significantly more complex in scope and in data input requirements than emissions inventory modeling. Users must (1) specify coordinates for sources of pollutants, (2) assign aircraft to runways, runway queues, taxiways, and gate areas, (3) develop appropriate operational profiles for mobile sources, (4) develop weather variables for individual hours, and (5) define other source specific parameters for each emissions source included in the dispersion analysis. The user is also required to define individual receptors or grids of receptors for pollutant concentration estimation. In preparing for the dispersion analyses, airport operations and physical planning data were assembled and documented for all three airports under consideration.

The methodology followed, and key assumptions made, during the dispersion modeling aspect of the study are described below.

Coordinates of Pollutant Sources

Coordinates for major point, area (e.g., parking lots), and line (e.g., roads, taxiways and runways) sources of pollutant emissions were derived from Airport Layout Plans maintained by the Clark County Department of Aviation. These plans provided configurations, lengths, and coordinates of runways and taxiways, commercial arrival/departure gates, and other airport facilities (boilers, generators, etc.) that are sources of CO emissions.

Airport Operational Profiles

Atmospheric dispersion of pollutants in EDMS is calculated for one hour periods. Because sources of CO pollution at airports vary in their activity and strength depending on the hour of the day, EDMS allows users to develop operational profiles to simulate peak activity periods. Operational profiles were defined for aircraft, ground access vehicles, and ground support equipment on the basis of available data including airline schedules. Peak period operations data used to develop aircraft operational profiles included: (1) monthly operations summaries by aircraft type; (2) daily operations summaries for the month of December; and (3) hourly operations summaries for an average day in December.

Aircraft Assignments

The EDMS dispersion module requires runway, taxiway, and gate assignments for each active aircraft in the study. This section summarizes the methodology used to perform these assignments. Additional information regarding aircraft gate and runway assignments is provided in the report *Carbon Monoxide Emissions Inventories and Dispersion Modeling, McCarran International, North Las Vegas, and Henderson Executive Airports* by Ricondo & Associates (1999).

The assignment of aircraft to airport runways at McCarran International Airport was based on information contained in the Federal Aviation Administration's (1994) report *Las Vegas McCarran International Airport, Capacity Enhancement Plan*, and confirmed through an analysis of historical hourly wind data (which defines takeoff/approach patterns) obtained from the National Climatic Data Center. Because the upgrade and lengthening of Runway 1L-19R to accommodate air carrier aircraft was completed in 1997, it was not modeled in the 1996 baseline scenario. Runway end assignments at North Las Vegas Airport and Henderson Executive Airport were based on information contained in recently completed Environmental Assessments.

The assignment of aircraft to passenger gate areas at McCarran International Airport was accomplished through a review of (1) aircraft landings data maintained by the Department of Aviation, and (2) existing and historical (1996) airline gate assignments. Gate assignments at North Las Vegas Airport were based on a review of aircraft landings data. At Henderson Executive Airport one gate area was modeled in EDMS.

The following runway/gate area assumptions were also incorporated in the EDMS modeling:

- Satellite D at McCarran International Airport was not included in the 1996 baseline scenario.
- A new international terminal facility would be constructed at McCarran International Airport by 2010. The new terminal facility would be located north of Satellite D.
- A new eastside basing facility would be constructed at North Las Vegas Airport prior to 2010. The new facility would be located east of the airfield.
- Runway 12L-30R would be constructed at North Las Vegas Airport sometime after the year 2000.
- Two new runways (17L-35R and 17R-35L) would be constructed at Henderson Executive Airport by 2010.

Meteorological Data

The EDMS uses five weather parameters in its dispersion modeling: temperature, wind speed, wind direction, Pasquill-Gifford Stability Classification, and mixing height. Meteorological data used in the dispersion modeling included National Weather Service hourly surface data from McCarran International Airport, and weather data contained in the County's UAM database for the exceedance episode.

The hourly meteorological data observations taken at McCarran include winds and temperature. Meteorological observation data are not available from North Las Vegas and Henderson airports, so the winds from the UAM gridded input database were extracted for these locations for use in EDMS. Temperatures from McCarran were used for all three airports. Hourly mixing height and stability measures were also taken from the UAM input database, and were assumed to be spatially constant. Utilizing UAM meteorological information wherever possible maximized the consistency between the two modeling techniques.

Grid Receptors

In the UAM, the Las Vegas Valley is represented by a grid of 2,500 one-kilometer grids cells (50x50 grid) for the emissions and dispersion estimation. To accurately measure airport-related CO concentrations in EDMS, a more refined grid of receptors was established for each airport. Each set of grid receptors was designed to subdivide and directly overlay the one-kilometer UAM grid. The EDMS grid resolution and the overall extent of the receptor grid for each airport was determined by running the UAM with and without airport emissions and comparing the resulting UAM CO concentration patterns. A receptor grid spacing of 250 meters was determined to adequately resolve the structure of the resulting dispersion pattern from the various airport sources. Based upon UAM results, it was necessary to define a rather expansive receptor grid for McCarran so that the full extent of the airport's CO concentration "footprint" (to 0.1 ppm) would be modeled with EDMS. The number of EDMS receptors defined for each airport is as follows:

McCarran International:	2501 (15x10 km)
North Las Vegas:	825 (8x6 km)
Henderson Executive:	221 (4x3 km)

ADDING EDMS RESULTS TO UAM CONCENTRATIONS

EDMS dispersion predictions for the 1996 episode and all future years were added to "background" concentrations derived from the UAM to obtain total CO concentrations. In this case, the UAM was run for the 1996 and future year base cases (i.e., no additional control strategies) with all airport-related emissions removed from the input emissions inventory so that contributions from airports would not be double-counted. For each hour of the simulation, UAM output predictions were bilinearly interpolated to each EDMS receptor and added to the corresponding EDMS concentration. To remain completely consistent with the UAM analyses, UAM concentrations were scaled by a factor of 1.14 for all years before being added to the EDMS results (see Emery et al. [1999] for the reasoning for this scaling factor). Finally, running 8-hour average total CO was then calculated for each receptor, and rank-ordered to determine if the maximum total 8-hour CO exceeded the NAAQS (9 ppm) anywhere in the EDMS domain. Results of this analysis are presented in the next section.

3. DISPERSION RESULTS

RANKED EDMS CONCENTRATIONS

The ten highest EDMS 8-hour CO concentrations for each modeling year are given in Tables 3-1 through 3-3 for McCarran International, North Las Vegas, and Henderson airports, respectively. The EDMS results are first shown without the addition of UAM concentrations to establish that the airport emissions alone, as modeled in this study, do not approach the 8-hour CO standard in any year.

Table 3-1. Rank-ordered peak 8-hour CO concentrations (ppm) estimated using EDMS at McCarran International Airport for four modeling years (all Base Case estimates assuming no additional County controls to on-road motor vehicles). The "period" indicates the hour range of maximum 8-hour CO concentration.

1996 Base			2000 Base			2010 Base			2020 Base		
Receptor	Period	CO	Receptor	Period	CO	Receptor	Period	CO	Receptor	Period	CO
470	15-23	3.00	470	15-23	2.30	469	01-09	5.61	469	01-09	6.26
470	16-24	2.84	470	16-24	2.17	469	03-11	4.96	469	03-11	5.58
511	18-02	2.33	511	18-02	1.73	469	02-10	4.92	469	02-10	5.52

511	17-01	2.32	511	17-01	1.72	469	00-08	4.17	469	00-08	4.65
470	03-11	1.94	470	03-11	1.54	469	21-05	3.97	469	21-05	4.42
511	16-24	1.92	511	16-24	1.51	469	23-07	3.62	469	23-07	4.03
511	19-03	1.64	629	16-24	1.44	469	22-06	3.46	469	22-06	3.85
511	15-23	1.61	629	17-01	1.42	469	18-02	3.42	469	18-02	3.81
470	17-01	1.61	629	15-23	1.40	469	19-03	3.38	469	19-03	3.77
511	23-07	1.46	511	15-23	1.29	469	20-04	3.21	469	20-04	3.58

Table 3-2. Rank-ordered peak 8-hour CO concentrations (ppm) estimated using EDMS at North Las Vegas Airport for four modeling years (all Base Case estimates assuming no additional County controls to on-road motor vehicles). The "period" indicates the hour range of maximum 8-hour CO concentration.

1996 Base			2000 Base			2010 Base			2020 Base		
Receptor	Period	CO	Receptor	Period	CO	Receptor	Period	CO	Receptor	Period	CO
268	15-23	0.42	316	03-11	0.39	268	15-23	0.55	316	03-11	0.51
268	16-24	0.37	292	03-11	0.38	268	16-24	0.49	292	03-11	0.50
292	03-11	0.36	316	02-10	0.37	292	03-11	0.46	316	02-10	0.50
292	02-10	0.34	292	02-10	0.37	316	03-11	0.45	292	02-10	0.49
316	03-11	0.34	268	15-23	0.37	292	02-10	0.45	268	15-23	0.45

316	02-10	0.33	268	16-24	0.33	316	02-10	0.44	268	03-11	0.45
268	17-01	0.33	316	01-09	0.33	268	17-01	0.43	316	01-09	0.44
316	01-09	0.29	268	03-11	0.32	316	01-09	0.38	268	02-10	0.42
292	01-09	0.28	292	01-09	0.30	292	01-09	0.37	268	16-24	0.40
316	00-08	0.25	268	17-01	0.30	268	03-11	0.34	292	01-09	0.40

Table 3-3. Rank-ordered peak 8-hour CO concentrations (ppm) estimated using EDMS at Henderson Executive Airport for four modeling years (all Base Case estimates assuming no additional County controls to on-road motor vehicles). The "period" indicates the hour range of maximum 8-hour CO concentration.

1996 Base			2000 Base			2010 Base			2020 Base		
Receptor	Period	CO	Receptor	Period	CO	Receptor	Period	CO	Receptor	Period	CO

92	15-23	0.14	92	15-23	0.19	89	15-23	0.14	89	15-23	0.20
92	16-24	0.11	92	16-24	0.19	89	16-24	0.14	89	16 -24	0.20
92	03-11	0.11	92	03-11	0.14	181	15-23	0.08	107	15 -23	0.10
91	15-23	0.09	91	15-23	0.12	181	16-24	0.08	107	16-24	0.10
91	16-24	0.09	91	16-24	0.12	107	15-23	0.07	146	15-23	0.10
91	17-01	0.09	91	17-01	0.12	107	16-24	0.07	146	16-24	0.10
93	03-11	0.06	93	03-11	0.08	181	17-01	0.07	198	15-23	0.10
93	15-23	0.06	93	15-23	0.08	168	15-23	0.05	198	16-24	0.10

93	16-24	0.05	93	16-24	0.07	168	16-24	0.05	146	17-01	0.10
110	15-23	0.04	110	15-23	0.06	198	15-23	0.05	131	15-23	0.09

From these results it is apparent that only CO from McCarran may be of concern in the 2010 and 2020 future years when combined with UAM results for those years. Also, the trend from 1996 to 2020 seems to include a shift in the timing of the 8-hour peak from a dominance in the late evening (4 PM to 12 midnight) in 1996 to more peaks during the following morning (2 AM to 10 AM) in 2010 and 2020.

RANKED TOTAL CONCENTRATIONS

To ascertain whether total 8-hour CO concentrations are estimated to exceed the standard anywhere in the airport EDMS modeling domains, EDMS estimates were added to gridded UAM output as described in Section 2. The analysis begins with McCarran due to it's large grid coverage, which may extend into areas of high predicted CO in the UAM grid, and the high estimated EDMS concentrations as shown above. In the following tables, the ranking is based on total 8-hour CO concentrations (EDMS + UAM), with the separate contributions from each model listed as well. Table 3-4 displays results for the McCarran 1996, 2000, 2010, and 2020 Base Cases.

In 1996 there are simulated exceedances of the 8-hour CO standard at 10 McCarran receptors, but these are solely a result of the UAM predictions (seven EDMS receptors are at 0.00 ppm, two are at 0.01 ppm, and one is at 0.12 ppm). This is a result of the large areal extent of the McCarran EDMS receptor grid, which reaches into the Spring Mountain Rd area where UAM predicts high concentrations. However, practically no emissions from McCarran are dispersed into that area. Thus, the highest concentrations from EDMS (2-3 ppm in 1996, Table 3-1) are very local to the airport, with commensurate UAM concentrations in that area being 1-2 ppm or less. These analyses suggest that McCarran is rather isolated from the main Las Vegas CO cloud that exists well to the north.

All predicted future year 8-hour CO levels are below the standard, except for one McCarran receptor in 2020 (9.07 ppm). The EDMS concentration at that point is only 0.17 ppm and the UAM component is 8.90 ppm. The future year UAM control strategy results reported by Emery et al. (1999) indicate that adoption of just one primary control measure (such as Cleaner Burning Gasoline) would reduce the overall peak UAM concentration from 10.8 ppm to 9.1 ppm, about a 16% reduction. Applying this same 16% reduction to the UAM concentration at the peak EDMS receptor would reduce the 8.90 ppm value to 7.50 ppm. Even assuming that this control measure has no effect on McCarran sources, the 9.07 ppm peak in Table 3-4 reduces to 7.67 under the Cleaner Burning Gasoline measure. Therefore, this analysis shows attainment in 2000, and maintenance of the standard in 2010 and 2020 with the adoption of Clark County's proposed primary control measures for CO.

Tables 3-5 and 3-6 list the peak 8-hour total CO receptor for each of the years modeled at North Las Vegas and Henderson Executive airports, respectively. The separate EDMS and UAM contributions are listed as well. At North Las Vegas, the peak CO is entirely a result of the UAM predictions, which approach the 8-hour standard in 1996 and 2020. Like the results for McCarran, the North Las Vegas EDMS receptor grid extends southward toward the high volume freeway intersection of I-15 and U.S. 95. However, EDMS does not disperse airport emissions into that area. Peak 8-hour total CO concentration in the Henderson EDMS grid is more balanced between the two models, but they remain very low (0.5-1 ppm total) for all years.

Table 3-4. Rank-ordered peak 8-hour total CO concentrations (ppm) on the McCarran Airport EDMS receptor grid for four modeling years (all Base Case estimates assuming no additional County controls to on-road motor vehicles). The "period" indicates the hour range of maximum 8-hour CO concentration. Also listed are the component EDMS and UAM CO concentrations for each total concentration given.

1996 Base Case				
Receptor	Period	Total CO	EDMS CO	UAM CO
277	03-11	9.64	0.00	9.64
277	02-10	9.56	0.00	9.56
278	03-11	9.39	0.00	9.39
278	02-10	9.30	0.00	9.30
318	02-10	9.24	0.00	9.24
318	03-11	9.18	0.00	9.18
236	03-11	9.08	0.01	9.07
276	03-11	9.07	0.01	9.06
319	02-10	9.03	0.00	9.03
1599	02-10	9.01	0.12	8.89
2000 Base Case				
Receptor	Period	Total CO	EDMS CO	UAM CO
277	03-11	8.66	0.01	8.66
277	02-10	8.59	0.00	8.59
278	03-11	8.37	0.00	8.37
318	02-10	8.33	0.00	8.33
278	02-10	8.30	0.00	8.30
318	03-11	8.27	0.00	8.27
276	03-11	8.19	0.01	8.18
236	03-11	8.17	0.01	8.16
319	02-10	8.08	0.00	8.08
276	02-10	8.08	0.00	8.08
2010 Base Case				
Receptor	Period	Total CO	EDMS CO	UAM CO
277	03-11	8.07	0.01	8.06
277	02-10	8.02	0.00	8.02
318	02-10	7.86	0.00	7.86
318	03-11	7.79	0.01	7.78
278	03-11	7.78	0.01	7.78
276	03-11	7.78	0.02	7.77

278	02-10	7.73	0.00	7.73
1599	02-10	7.70	0.12	7.58
359	02-10	7.69	0.00	7.69
276	02-10	7.69	0.00	7.67
2020 Base Case				
Receptor	Period	Total CO	EDMS CO	UAM CO
1599	02-10	9.07	0.17	8.90
1598	02-10	8.94	0.18	8.76
277	03-11	8.85	0.01	8.84
1558	02-10	8.82	0.16	8.66
1599	01-09	8.81	0.18	8.63
277	02-10	8.80	0.00	8.79
1599	03-11	8.78	0.17	8.61
1597	02-10	8.78	0.18	8.59
1640	02-10	8.73	0.18	8.55
1557	02-10	8.72	0.17	8.55

Table 3-5. Peak 8-hour total CO concentrations (ppm) on the North Las Vegas Airport EDMS receptor grid for four modeling years (all Base Case estimates assuming no additional County controls to on-road motor vehicles). The "period" indicates the hour range of maximum 8-hour CO concentration. Also listed are the component EDMS and UAM CO concentrations for each total concentration given.

Scenario	Receptor	Period	Total CO	EDMS CO	UAM CO
1996 Base	801	18-02	8.89	0.00	8.89
2000 Base	801	18-02	7.54	0.00	7.54
2010 Base	801	18-02	7.03	0.00	7.03
2020 Base	801	18-02	8.27	0.01	8.27

Table 3-6. Peak 8-hour total CO concentrations (ppm) on the Henderson Executive EDMS receptor grid for four modeling years (all Base Case estimates assuming no additional County controls to on-road motor vehicles). The "period" indicates the hour range of maximum 8-hour CO concentration. Also listed are the component EDMS and UAM CO concentrations for each total concentration given.

Scenario	Receptor	Period	Total CO	EDMS CO	UAM CO
1996 Base	92	16-24	0.57	0.14	0.43

2000 Base	92	16-24	0.58	0.19	0.39
2010 Base	204	16-24	0.55	0.04	0.51
2020 Base	181	16-24	1.17	0.09	1.08

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APPENDIX C

Section Eight
Carbon Monoxide Emissions Inventory and Dispersion Modeling from McCarran International, North Las Vegas, and Henderson Executive Airports (Airport 2)

Carbon Monoxide Emissions Inventory
And
Dispersion Modeling

McCarran International, North Las Vegas
and Henderson Executive airports

Prepared for:
Clark County Department of Aviation

Prepared by:
Ricondo & Associates, Inc.

In association with:
ENVIRON International Corporation

July 27, 1999

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I. INTRODUCTION

The Clark County Department of Comprehensive Planning is in the process of demonstrating attainment of the National Ambient Air Quality Standards (NAAQS) for carbon monoxide (CO) as part of a revised State Implementation Plan (SIP) for the Las Vegas Valley. The SIP is to be completed in 1999 and will be based on modeling results using the Urban Airshed Model (UAM) for a particular 20-hour exceedance episode that occurred in December 1996.

Preliminary air quality modeling results show that on-road motor vehicles are the dominant source of CO emissions in the Valley and that adoption of certain controls on mobile sources, specifically automobiles, should result in successful attainment of the federal 8-hour CO standard (9 parts per million) by the year 2000. However, there is some uncertainty regarding emissions from other types of mobile sources. Some of these sources contribute a minor fraction to the total CO emissions in the Las Vegas Valley and operate outside of the periods associated with the highest ambient CO concentration. However, it is postulated that contributions from airport sources can be better represented than they are currently in the UAM. The complexity of airport sources combined with the fact that airport-related emissions are usually confined to a small area make them difficult to model in a grid-based model like the UAM. The fine scale emissions distributions at airport facilities requires the use of a "micro-scale" modeling approach, such as would be used to model emissions associated with a high volume traffic intersection, where CAL3QHC is used as a supplement to the UAM. For this reason, the County has decided to evaluate airport emissions associated with the primary County owned and operated airports using the United States Air Force/Federal Aviation Administration Emissions and Dispersion Modeling System (EDMS).

This report documents (1) the carbon monoxide (CO) emissions inventories conducted for the 1996 base year, the 2000 attainment year, and future years 2010 and 2020 for McCarran International Airport, North Las Vegas Airport, and Henderson Executive Airport, and (2) the methodology employed to perform atmospheric dispersion of base year (1996) and future-year airport-related CO emissions. The combination of CO concentration values estimated by the EDMS with CO concentration values derived from the Department of Comprehensive Planning's Urban Airshed Model is described in the report, *Dispersion Modeling of Carbon Monoxide Emissions From Three Clark County Airports in Support of the Revised SIP*.

II. EMISSIONS AND DISPERSION MODELING SYSTEM

The development of airport CO emissions inventories and the atmospheric dispersion of airport-related CO emissions were conducted using EDMS. EDMS is a combined emissions and dispersion model developed by the Federal Aviation Administration (FAA) in cooperation with the United States Air Force (USAF). The primary applications of the model are generating an inventory of emissions caused by sources on and around an airport or air base and calculating pollutant concentrations in the surrounding environment. Pollutants currently included in EDMS for dispersion analyses are carbon monoxide (CO), oxides of nitrogen (NOx), oxides of sulfur (SOx), and particulate matter less than 10 microns in diameter (PM-10).

The back-end for both the emissions inventory and dispersion modeling components of EDMS is a comprehensive database comprised of tables for system data and user-created sources and results. System data tables include emissions factors for civilian and military aircraft, civilian ground support equipment, and civilian motor vehicles. Civilian motor vehicle emissions factors are based on MOBILE5a modeling for vehicle fleets between 1997 and the year 2020. Both the emissions inventory and dispersion modeling modules interact with the system database to retrieve and store data.

The EDMS emissions inventory module incorporates EPA-approved methodologies for calculating aircraft emissions, on- and off-road vehicle emissions, and stationary source emissions. The dispersion module incorporates the PAL 2 and CALINE 3 dispersion models—both of which are EPA validated for the various sources of emissions present at airports. The PAL 2 and CALINE 3 dispersion models are based on assumptions and have known limitations regarding their application. Assumptions used in the dispersion analysis module include: a simple or relatively flat terrain, conservation of mass (i.e., negligible chemical breakdown of original substance), and steady state atmospheric conditions over the averaging period of one hour. Additionally, Gaussian dispersion algorithms used by EDMS are limited to transport distances of less than 50 kilometers and do not consider complex aerodynamic effects such as downwash from buildings. Nevertheless, EDMS is the Environmental Protection Agency's (EPA's) preferred guideline model for air quality analyses at airports.

III. AIRPORT-RELATED EMISSIONS

The EDMS was used to estimate airport-related CO emissions from the following sources:

- Aircraft
- Ground service equipment (GSE)
- Ground access vehicles (associated with movements on roadways and in parking lots)
- Point sources, such as power and heating plants, incinerators, fuel tanks, and surface coating facilities

The methodologies and assumptions incorporated in the base and future year CO emissions inventories are described in the sections that follow. A detailed discussion of the CO dispersion process is provided in Section V.

3.1 Aircraft Emissions

Annual aircraft emissions are a function of the number of annual aircraft operations, expressed as landing and takeoff (LTO) cycles, the aircraft fleet mix (types of aircraft used), and the length of time aircraft spend taxiing and idling on the ground. The EDMS database contains an expansive list of aircraft types (airframes) and engine types for use in air quality analyses. Emissions associated with individual aircraft operations are a function of the aircraft operating mode (i.e. taxi/idle, takeoff, etc.), aircraft engine type, and are estimated using emissions factors associated with particular engine types and operating modes. Key assumptions made regarding aircraft-related CO emissions follow.

3.1.1 Aircraft LTO Cycles and Fleet Mix.

Tables 1, 2, and 3 summarize 1996 annual LTO cycles by EDMS aircraft type and engine type for McCarran International, North Las Vegas, and Henderson Executive airports, respectively. Information contained in the tables is based on data provided by the Clark County Department of Aviation and supplemental sources as noted below.

- For McCarran International Airport, historical aircraft activity (LTO cycles) and fleet mix inputs were based on summaries of operations prepared by the Department of Aviation using data provided by the FAA Airport Traffic Control Tower (ATCT) and data contained in the report *Noise Contour Update-1997/98, McCarran International Airport,* prepared by Brown-Buntin Associates, Inc. Aircraft engine types modeled for each aircraft type (airframe) were identified by Ricondo & Associates using (1) information obtained from Back Information Services, and (2) airline operations summaries obtained from Department of Aviation.

- For North Las Vegas Airport, historical aircraft activity (LTO cycles) inputs were based on summaries of operations prepared by the Department of Aviation using data provided by the FAA Airport Traffic Control Tower (ATCT). The aircraft fleet mix was based on information contained in the report *Final Environmental Assessment, Runway 12L-30R, North Las Vegas,* prepared by Leigh Fisher Associates. Default EDMS engine types were used for all aircraft types modeled for North Las Vegas Airport.

- For Henderson Executive Airport, historical aircraft activity (LTO cycles) inputs were based on summaries of operations prepared by the Department of Aviation using data provided by the FAA Airport Traffic Control Tower (ATCT). The 1996 aircraft fleet mix is based on information contained in the report *Final Environmental Assessment, Master Plan Report Recommendations, Henderson Executive Airport,* prepared by Leigh Fisher Associates. EDMS default engine types were used for all aircraft types modeled in EDMS.

Table 1

1996 Aircraft Fleet Mix and Annual LTO Cycles – McCarran International Airport

Aircraft type	EDMS type	Engine type	1996 Annual LTO Cycles (a)
Air carrier			
A320	A320	V2500A-1	4,080
A320	A320-200	V2527-A5	6,024
A300/310	A300	CF6-50C	232
B727	727-200	JT8D-9	219
B727	727-200	JT8D-9A	1,312
B727	727-200	JT8D-15	7,131
B727	727-200	JT8D-17	325
B737-200 (a)	737-200	JT8D-9A	7,383
B737-200	737-200	JT8D-15	7,769
B737-200	737-200	JT8D-17	172
B737-300/400/500	737-300	CFM56-3	60,357
B737-300/400/500	737-300	CFM56-3B	13,431
B737-300/400/500	737-300	CFM56-3C1	3,802
B747	747-200	Default	163
B757	757-200	PW2037	6,538
B757	757-200	PW2040	806
B757	757-200	RB211-535C	6,268
B767	767-200	Default	3,557
DC10	DC10-30	Default	2,218
DC9	DC9-30	Default	630
L1011	L1011	Default	1,371
MD80	MD80	JT8D-2171	4,179
MD80	MD80	JT8D-219	2,635
MD80	MD90-10	MD90/V2525-D5	5
Subtotal			140,607
Air taxi/commuter			
30-50 passengers	Dash 8	PW120	10,265
19 passengers	Dash 6	PT6A-27	15,540
Multiengine piston	Aztec	TIO-540-J2B2	10,194
Subtotal			35,999
General aviation			
Business jet	Lear 25	CJ610-6	15,971
Twin engine turboprop	King Air 200	PT6A-41	10,859
Twin engine piston prop	Aztec	TIO-540-J2B2	8,625
Single engine piston prop	Cherokee 6	TIO-540-J2B2	16,927
Subtotal			52,382
Military			
Fighter/Trainer	F16	F100-PW-100	2,357
Twin engine turboprop	C130	T56-A-16	6,910
Subtotal			9,267
Total annual LTO cycles			238,255

(a) LTO = Landing and takeoff. One LTO cycle equals two operations: a landing and a takeoff.

Source: Ricondo & Associates, Inc. based on operations data provided by the Clark County Department of Aviation, fleet mix data provided by Brown-Buntin Associates, Inc. and data obtained from Back Information Services.

Prepared by: Ricondo & Associates, Inc.

Table 2

1996 Aircraft Fleet Mix and Annual LTO Cycles – North Las Vegas Airport

Aircraft type	EDMS type	Engine type	1996 Annual LTO cycles (a)	1996 Annual TG cycles (b)
Itinerant Operations				
Single-engine piston prop	Cherokee 6	TIO-540-J2B2	7,692	0
Single-engine piston prop	Cessna 150	O-200	21,456	0
Twin-engine piston prop	Piper Navajo	TIO-540-J2B2	6,205	0
Twin-engine turboprop	King Air 200	PT6A-41	996	0
Twin-engine turboprop	Dash 6	PT6A-27	996	0
Business Jet	Lear 24	TFE-731-2-2B	957	0
Subtotal			38,302	0
Local Operation				
Single-engine piston prop	Cherokee 6	TIO-540-J2B2	0	12,095
Single-engine piston prop	Cessna 150	O-200	0	32,651
Twin-engine piston prop	Piper Navajo	TIO-540-J2B2	0	9,306
Twin-engine turboprop	King Air 200	PT6A-41	0	1,672
Twin-engine turboprop	Dash 6	PT6A-27	0	0
Subtotal			0	55,724
Air taxi Operations				
Single-engine piston prop	Cherokee 6	TIO-540-J2B2	1,316	0
Single-engine piston prop	King Air 200 (c)	PT6A-41	1,959	0
Twin-engine piston prop	Piper Navajo	TIO-540-J2B2	19,725	0
Twin-engine turboprop	Dash 6	PT6A-27	15,297	0
Subtotal			38,297	0
Total annual cycles			76,599	55,724

(a) LTO = Landing and takeoff. One LTO cycle equals two operations: a landing and a takeoff.
(b) TG = Touch and go. One touch-and-go equals two local operations.
(c) Modeled in EDMS as a King Air 200 with operations divided by 2 to adjust to a single engine.

Source: Ricondo & Associates, Inc. based on operations data provided by the Clark County Department of Aviation, and fleet mix information contained in the report *Final Environmental Assessment, Proposed Runway 12L-30R, North Las Vegas Airport*.

Prepared by: Ricondo & Associates, Inc.

Table 3

1996 Aircraft Fleet Mix and Annual LTO Cycles – Henderson Executive Airport

Aircraft Type	EDMS Type	Engine Type	1996 Annual LTO Cycles (a)	1996 Annual TG Cycles (b)
Air Taxi				
Single-engine piston prop	Cherokee 6	TIO-540-J2B2	1,942	0
Single-engine turboprop	King Air 200 (c)	PT6A-41	2,689	0
Twin-engine turboprop	Dash 6	PT6A-27	7,619	0
Subtotal			12,250	0
Itinerant General Aviation				
Single-engine piston prop	Cherokee 6	TIO-540-J2B2	2,555	0
Single-engine piston prop	Cessna 150	0-200	3,606	0
Twin-engine piston prop	Piper Navajo	TIO-540-J2B2	1,201	0
Twin-engine Turboprop	King Air 200	PT6A-41	388	0
Subtotal			7,750	0
Local General Aviation				
Single-engine piston prop	Cherokee 6	TIO-540-J2B2	0	3,324
Single-engine piston prop	Cessna 150	0-200	0	4,817
Twin-engine piston prop	Piper Navajo	TIO-540-J2B2	0	909
Twin-engine Turboprop	King Air 200	PT6A-41	0	0
Subtotal			0	9,050
Total annual cycles			20,000	9,050

(a) LTO = Landing and takeoff. One LTO cycle equals two operations: a landing and a takeoff.
(b) TG = Touch and go. One touch-and-go equals two local operations.
(c) Modeled in EDMS as a King Air 200 with operations divided by 2 to adjust to a single engine.

Source: Ricondo & Associates, Inc. based on operations data provided by the Clark County Department of Aviation, and fleet mix information contained in the report *Final Environmental Assessment, Master Plan Report Recommendations, Henderson Executive Airport*.

Prepared by: Ricondo & Associates, Inc.

Forecasts of annual LTO cycles by EDMS aircraft type were prepared by Ricondo & Associates, Inc. for each airport for 2000, 2010, and 2020. These forecasts, summarized in **Tables 4, 5, and 6**, are based on a host of assumptions contained in existing planning studies and on the FAA's latest Terminal Area Forecast for McCarran International Airport. Key forecast assumptions are discussed in the bullets below:

- At McCarran International Airport, air carrier and air taxi operations are assumed to increase at an annual rate of 3.08%. This growth rate is consistent with the FAA's Terminal Area Forecast for McCarran International Airport and regional population projections prepared by the Regional Transportation Commission (RTC). The numbers of general aviation and military operations at McCarran International Airport are assumed to remain constant through 2020. The aircraft fleet mix is expected to change somewhat during the forecast period as noisier stage 2 aircraft are phased out of the fleet. It is also expected that older generation Boeing 737 aircraft will be replaced with newer aircraft including Boeing 737-600's and 737-700's.

- At North Las Vegas Airport, aircraft operations are assumed to increase at an annual rate of .5% through the forecast period. This growth rate is consistent with assumptions set forth in the *Final Environmental Assessment, Proposed Runway 12L-30R, North Las Vegas Airport*. The aircraft fleet mix and split between air taxi and general aviation operations is assumed to remain constant.

- The numbers of general aviation and air tour operations at Henderson Executive Airport are assumed to increase at an annual rate of 7.8% through 2000 and at an annual rate of 3.7% between 2000 and 2020, consistent with assumptions in the *Final Environmental Assessment, Master Plan Report Recommendations, Henderson Executive Airport*. The aircraft fleet mix and split between air tour and general aviation operations is assumed to remain constant.

3.1.2 Aircraft Taxi Time

The EDMS incorporates default operating times for the taxi-in and taxi-out modes of operation for each aircraft type contained in the model database. For commercial aircraft, a default time of 26 minutes is assumed. For general aviation (GA) aircraft, default times of 16 minutes for piston engine aircraft and 12 minutes for turbine engine aircraft are assumed. These taxi times include the time required to taxi to and from the runways as well as any delays encountered while the aircraft is on the ground.

To ensure that the emissions inventories appropriately accounted for and, in particular, did not underestimate aircraft taxi-in and taxi-out emissions, taxi times were investigated to determine if actual times were different from default values in the EDMS. Taxi times at each airport were investigated using the methodologies described below.

Table 4

Forecast Fleet Mix and Annual LTO Cycles – McCarran International Airport

			Forecast LTO Cycles (a)		
Aircraft Type	**EDMS Type**	**Engine Type**	**2000**	**2010**	**2020**
Air carrier jet					
A320	A320	V2500A-1	4,431	6,001	8,128
A320	A300-200	V2527-A5	6,542	8,861	12,001
A300/310	A300	CF6-50C	252	341	462
B727	727-200	JT8D-9	238	323	437
B727	727-200	JT8D-9A	1,425	1,929	2,613
B727	727-200	JT8D-15	7,744	10,489	14,206
B727	727-200	JT8D-17	352	477	647
B737-200 (b)	737-200	JT8D-9A	8,019	0	0
B737-200	737-200	JT8D-15	8,438	4,500	4,500
B737-200	737-200	JT8D-17	186	0	0
B737-300/400/500	737-300	CFM56-3	65,552	93,051	127,622
B737-300/400/500	737-300	CFM56-3B	14,587	21,708	29,400
B737-300/400/500	737-300	CFM56-3C1	4,129	6,145	8,322
B737-600/700	737-700	CFM56-3C1	0	11,270	15,265
B747	747-200	Default	177	240	325
B757	757-200	PW2037	7,100	9,617	13,025
B757	757-200	PW2040	876	1,186	1,606
B757	757-200	RB211-535C	6,808	9,220	12,488
B767	767-200	Default	3,864	5,233	7,087
DC10	DC10-30	Default	2,409	3,262	4,418
DC9	DC9-30	Default	685	927	1,256
L1011	L1011	Default	1,489	2,017	2,731
MD80	MD80	JT8D-2171	4,539	6,148	8,327
MD80	MD80	JT8D-219	2,862	3,876	5,249
MD80	MD90-10	MD90/V2525-D5	6	8	10
subtotal			152,710	206,828	280,127
Air Taxi/commuter					
30-50 passengers	Dash 8	PW120	11,149	15,099	20,451
19 passengers	Dash 6	PT6A-27	16,877	22,858	30,959
Multiengine piston	Aztec	TIO-540-J2B2	11,072	14,996	20,310
subtotal			39,098	52,953	71,720
General Aviation					
Business Jet	Lear 25	CJ610-6	15,971	15,971	15,971
Twin engine turboprop	King Air 200	PT6A-41	10,859	10,859	10,859
Twin engine piston prop	Aztec	TIO-540-J2B2	8,625	8,625	8,625
Single engine piston prop	Cherokee 6	TIO-540-J2B2	16,927	16,927	16,927
subtotal			52,382	52,382	52,382
Military					
Fighter/Trainer	F16	F100-PW-100	2,357	2,357	2,357
Twin engine turboprop	C130	T56-A-16	6,910	6,910	6,910
subtotal			9,267	9,267	9,267
Total annual cycles			253,456	321,430	413,496

(a) LTO = Landing and takeoff. One LTO cycle equals two operations: a landing and a takeoff.
(b) 737s adjusted to reflect introduction of newer aircraft in future years.

Source: Ricondo & Associates, Inc. based on the FAA's Terminal Area Forecast for McCarran International Airport.
Prepared by: Ricondo & Associates, Inc.

Table 5

Forecast Fleet Mix and Annual LTO Cycles – North Las Vegas Airport

Aircraft Type	EDMS Type	Engine Type	Forecast LTO/TG Cycles (a) 2000	2010	2020
Itinerant Operations					
Single-engine piston prop	Cherokee 6	TIO-540-J2B2	9,746	10,245	10,768
Single-engine piston prop	Cessna 150	O-200	27,185	28,575	30,036
Twin-engine piston prop	Piper Navajo	TIO-540-J2B2	7,861	8,263	8,686
Twin-engine turboprop	King Air 200	PT6A-41	1,261	1,326	1,394
Twin-engine turboprop	Dash 6	PT6A-27	1,261	1,326	1,394
Business Jet	Lear 24	TFE-731-2-2B	1,213	1,275	1,340
Subtotal			48,528	51,009	53,618
Local Operations (b)					
Single-engine piston prop	Cherokee 6	TIO-540-J2B2	15,324	16,108	16,931
Single-engine piston prop	Cessna 150	O-200	41,368	43,484	45,707
Twin-engine piston prop	Piper Navajo	TIO-540-J2B2	11,791	12,394	13,027
Twin-engine turboprop	King Air 200	PT6A-41	2,118	2,227	2,341
Twin-engine turboprop	Dash 6	PT6A-27	0	0	0
Subtotal			70,601	74,211	78,007
Air Taxi Operations					
Single-engine piston prop	Cherokee 6	TIO-540-J2B2	1,668	1,753	1,843
Single-engine piston prop	King Air 200 (c)	PT6A-41	2,482	2,609	2,742
Twin-engine piston prop	Piper Navajo	TIO-540-J2B2	24,991	26,269	27,613
Twin-engine turboprop	Dash 6	PT6A-27	19,380	20,372	21,413
Subtotal			48,521	51,003	53,611
Total annual cycles			167,650	176,224	185,236

(a) LTO = Landing and takeoff. One LTO cycle equals two operations: a landing and a takeoff.
(b) All local operations are assumed to be touch-and-go operations
(c) Modeled in EDMS as a King Air 200 with operations divided by 2 to adjust to a single engine.

Source: Ricondo & Associates, Inc. based on information contained in the report *Final Environmental Assessment, Proposed Runway 12L-30R, North Las Vegas Airport*.
Prepared by: Ricondo & Associates, Inc.

Table 6

Forecast Fleet Mix and Annual LTO Cycles – Henderson Executive Airport

Aircraft Type	EDMS Type	Engine Type	Forecast LTO/TG Cycles(a) 2000	2010	2020
Air Taxi					
Single-engine piston prop	Cherokee 6	TIO-540-J2B2	2,622	3,771	5,423
Single-engine turboprop	King Air 200 (c)	PT6A-41	3,632	5,223	7,510
Twin-engine turboprop	Dash 6	PT6A-27	10,289	14,797	21,279
Subtotal			16,543	23,790	34,213
Itinerant General Aviation					
Single-engine piston prop	Cherokee 6	TIO-540-J2B2	3,450	4,962	7,136
Single-engine piston prop	Cessna 150	0-200	4,870	7,004	10,072
Twin-engine piston prop	Piper Navajo	TIO-540-J2B2	1,622	2,333	3,355
Twin-engine Turboprop	King Air 200	PT6A-41	523	753	1,082
Subtotal			10,466	15,051	21,645
Local General Aviation (d)					
Single-engine piston prop	Cherokee 6	TIO-540-J2B2	4,488	6,455	9,282
Single-engine piston prop	Cessna 150	0-200	6,506	9,356	13,455
Twin-engine piston prop	Piper Navajo	TIO-540-J2B2	1,227	1,765	2,539
Subtotal			12,221	17,576	25,275
Total annual cycles			39,230	56,417	81,133

(a) LTO = Landing and takeoff. One LTO cycle equals two operations: a landing and a takeoff.
(b) Modeled in EDMS as a King Air 200 with operations divided by 2 to adjust to a single engine.
(c) All local operations are assumed to be touch-and-go operations.

Source: Ricondo & Associates, Inc. based on information contained in the report *Final Environmental Assessment, Master Plan Report Recommendations, Henderson Executive Airport*.

Prepared by: Ricondo & Associates, Inc.

- For McCarran International Airport, data from the FAA's Consolidated Operations and Delay Analysis System (CODAS) were used to estimate average taxi times for commercial aircraft. CODAS data are collected for scheduled air carriers and reflect the actual taxi times for individual aircraft. Average taxi times for general aviation aircraft at McCarran International Airport were estimated by calculating an average taxi distance from the west-side general aviation facilities to Runways 1L-19R and 1R-19L and calculating the time required at typical taxi speeds and typical delays to cover the distance. On the basis of these analyses, default taxi in/out times contained in the EDMS database were found to be suitable and were used for all aircraft in the 1996 baseline scenario.

- It is assumed that the taxi-out delay at McCarran International Airport will increase as the volume of aircraft movements during peak operating periods nears the capacity of the airfield in its existing configuration. To account for this additional delay, aircraft taxi in/out times were increased by 7 minutes in the 2010 EDMS modeling scenario. By 2020 it was assumed that average taxi times would increase by as much as 14 minutes.

- For both North Las Vegas and Henderson Executive airports, average taxi times for air tour operations and general aviation aircraft were estimated using a similar methodology to that used to estimate general aviation aircraft taxi times at McCarran International Airport. On the basis of the results of taxi time analyses, default EDMS taxi in/out times were assumed for all aircraft at North Las Vegas Airport and Henderson Executive Airport.

3.2 Ground Service Equipment

Ground service equipment (GSE) includes a wide range of vehicles that are used to service aircraft. Examples of GSE include tugs that haul baggage carts and other equipment, fuel trucks, catering trucks and other service vehicles, and auxiliary power units (APUs) and ground power units (GPUs) that provide electrical power to aircraft when they are parked and the engines are not running. The EDMS database includes default GSE assignments for each aircraft type expressed in terms of total operating times by specific type of GSE per LTO cycle.

For McCarran International Airport, default EDMS GSE were compared with the results of a GSE inventory conducted by the Clark County Department of Aviation in 1996. On the basis of this comparison, EDMS default assignments of equipment type were revised to reflect the proportion of equipment in the 1996 inventory which is summarized in **Table 7**. GSE assignments and assumed GSE operating times by aircraft category are summarized in **Table 8**.

For North Las Vegas and Henderson Executive airports it was assumed that general aviation aircraft are fueled by trucks. For air tour operators, it was assumed that fuel trucks and auxiliary power units (APUs) are required. GSE equipment types and operating times for North Las Vegas Airport and Henderson Executive Airport are summarized in **Tables 9 and 10** respectively.

Table 7

1996 Ground Service Equipment Inventory – McCarran International Airport

	Number of Units				
GSE type	Diesel	Gasoline	Electric	Propane	Total
Air conditioner	8	1	--	--	9
Aircraft stairs	3	3	--	--	6
Air start	9	4	1	--	14
Belt loader	9	79	--	--	88
Bob tail	--	6	--	--	6
Cabin service truck	1	3	--	--	4
Cherry picker	--	3	1	--	4
Container loader	4	--	--	--	4
Deicer	2	4	--	--	6
Fork lift	--	7	--	5	12
Fuel tanker	2	4	--	--	6
Golf cart	--	4	4	--	8
Ground Power unit	8	2	--	--	10
High lift	1	10	--	--	11
Hoist	--	1	--	--	1
Hydrant	--	28	--	--	28
Hydraulic loader	6	2	--	--	8
Lavatory truck	1	9	--	--	10
Lavatory waste	--	1	--	--	1
Pushback	18	10	--	2	30
Scrubber	--	1	--	--	1
Support vehicle	--	44	--	--	44
Tug	14	89	3	1	107
Water cart	--	--	3	--	3
Total	86	315	12	8	421

GSE = Ground service equipment.

Source: Ricondo & Associates, Inc. based on responses to the 1996 GSE survey for McCarran International Airport conducted by the Clark County Department of Aviation.

Prepared by: Ricondo & Associates, Inc.

Table 8

Ground Service Equipment Operating Times – McCarran International Airport

	Equipment Operating Time (minutes per LTO cycle)		
GSE Type by Aircraft Category	**Diesel**	**Gasoline**	**Total**
Wide Body Aircraft			
Aircraft Tug Wide	4.8	2.7	8
Airstart Transporter	1.9	0.9	3
Airstart Unit	1.9	0.9	3
Bag Tug	11.1	70.7	85
Belt Loader	4.9	43.1	48
Cabin Service	3.7	11.3	15
Container Loader	92	0	92
Fuel Truck	11.7	23.3	35
Lavatory Truck	2	18	20
Food Truck	0	35	35
Transporter	0	10	10
Water Truck	0	12	12
Auxiliary Power Unit (APU)	0	26	26
Narrow Body			
Aircraft Tug Narrow	3.6	2	6
Bag Tug	11.1	70.7	85
Belt Loader	4.9	43.1	48
Cabin Service	3.8	11.3	15
Fuel Truck	11.7	23.3	35
Lavatory Truck	2	18	20
Food Truck	0	35	35
Auxiliary Power Unit (APU)	0	26	26
Air Tour/General Aviation			
Aircraft Tug Narrow	0	6	6
Fuel Truck	0	6	6
Ground Power Unit (GPU)	0	30	30

GSE = Ground Service Equipment
LTO = Landing and Takeoff

Note: GSE equipment powered by propane is not included in EDMS database.

Source: Ricondo & Associates, Inc.
Prepared by: Ricondo & Associates, Inc.

Table 9
Ground Service Equipment Operating Times – North Las Vegas Airport

GSE Type by Aircraft Category	Equipment Operating Time (minutes per LTO cycle) Diesel	Gasoline	Total
Cessna 150, Cherokee Six, Navajo			
Aircraft Tug Narrow	0	0.5	0.5
Fuel Truck	0	5.6	5.6
Transporter	0	1.31	1.31
DHC-6, KingAir 200, Lear 35/36			
Aircraft Tug Narrow	0	0.5	0.5
Fuel Truck	12.8	0	12.8
Transporter	0	1.31	1.31
APU GTCP 36 (80 HP)	0	1.53	1.53

APU = Auxiliary Power Unit
LTO = Landing and Takeoff

Source: Clark County Department of Aviation, April 1999
Prepared by: Ricondo & Associates, Inc.

Table 10
Ground Service Equipment Operating Times – Henderson Executive Airport

GSE Type by Aircraft Category	Equipment Operating Time (minutes per LTO cycle) Diesel	Gasoline	Total
Cessna 150, Cherokee Six, Navajo			
Aircraft Tug Narrow	0	3.6	3.6
Fuel Truck	0	6	6
DHC-6, KingAir 200			
Aircraft Tug Narrow	0	3.6	3.6
Fuel Truck	0	13.5	13.5
APU GTC 85	0	3	3

APU = Auxiliary Power Unit
LTO = Landing and Takeoff

Source: Clark County Department of Aviation, April 1999
Prepared by: Ricondo & Associates, Inc.

3.3 Point Sources

Emissions sources at airports include power generating and heating plants, incinerators, fuel storage tanks, and surface coating facilities. For the Clark County airport emissions inventories and dispersion analyses, facilities owned and controlled by the Clark County Department of Aviation were modeled in the EDMS. Point sources not operated by the Clark County Department of Aviation but on airport property were not modeled in EDMS. It was assumed that these sources will be accounted for elsewhere in the SIP.

Tables 11, 12 and 13 present a summary of point sources at McCarran International, North Las Vegas, and Henderson Executive airports, respectively. The tables also provide information regarding the volume of fuel consumed by the various point sources at each airport.

Table 11
Point Source Emissions Data – McCarran International Airport

Source	Type	Tank capacity (gallons)	Annual gallons used
Terminal 2 generator	Diesel fuel	700	259
North finger generator	Diesel fuel	600	222
Bridge area generator	Diesel fuel	1,000	370
Rotunda Terminal 1 generator	Diesel fuel	1,000	370
Heating and refrigeration plant	Diesel fuel	12,000	4,444
Heating and refrigeration plant	Diesel fuel	12,000	4,444
Clark County Fire Department Station 13	Diesel fuel	2,000	741
Clark County Fire Department Station 13	Diesel fuel	500	185
Clark County Fire Department Station 13	Waste oil	500	n.a.
South Finger generator	Diesel fuel	6,000	2,222
Satellite 1 generator	Diesel fuel	1,500	556
East Airfield lighting vault generator	Diesel fuel	500	185
Department of Aviation shop	Diesel fuel	6,000	20,000
Department of Aviation shop	Unleaded gasoline	10,000	195,000
Surface coating facility degreasers	Solvents	30	1,900
Paint booth	Enamels	n.a	24
Paint booth	Lacquer	n.a.	24
Paint booth	Cleaning solvent	n.a.	3
Paint booth	Primer	n.a.	12
Central Plant boilers	Natural gas	n.a.	n.a.

n.a. = Not available

Source: Leigh Fisher Associates, *Air Pollutant Emission Inventory, McCarran International, North Las Vegas, and Henderson Executive Airports*.
Prepared by: Ricondo & Associates, Inc.

Table 12

Point Source Emissions Data – North Las Vegas Airport

Source	Type	Tank capacity (gallons)	Annual gallons used
Light trailer generator	Diesel fuel	n.a.	100
ATCT emergency backup generator	Diesel fuel	n.a.	400
80 Octane fuel truck	Gasoline	2,000	31,232
Jet A tank #1	Jet A fuel	2,000	460,095
Jet A tank #2	Jet A fuel	2,000	87,571
Jet A tank #3	Jet A fuel	2,000	1,038,457
Low lead fuel truck	Avgas	1,200	394,631
Low lead fuel truck #2	Avgas	2,000	100,500
Low lead fuel truck #3	Avgas	2,000	308,196
Low lead fuel truck #4	Avgas	2,000	92,965
Low lead fuel truck #5	Avgas	2,000	81,115
Low lead fuel tank	Avgas	2,000	1,049,122
Low lead fuel tank #2	Avgas	2,000	1,049,122
Unleaded tank	Gasoline	600	11,367

ATCT = Airport traffic control tower
n.a. = Not available

Source: Leigh Fisher Associates, *Air Pollutant Emissions Inventory, McCarran International, North Las Vegas, and Henderson Executive Airports*.
Prepared by: Ricondo & Associates, Inc.

Table 13

Point Source Emissions Data – Henderson Executive Airport

Source	Type	Tank capacity (gallons)	Annual gallons used
Jet A tank #1	Jet A fuel	10,000	476,564
Jet A tank #2	Jet A fuel	10,000	476,564
Avgas tank #1	Avgas	10,000	95,141
Avgas tank #2	Avgas	12,000	255,223
Gasoline storage tank	Gasoline	600	5,633

Source: Leigh Fisher Associates, *Air Pollutant Emissions Inventory, McCarran International, North Las Vegas, and Henderson Executive Airports*.
Prepared by: Ricondo & Associates, Inc.

3.4 On-Road Motor Vehicles

Motor vehicle traffic on roadways and in airport parking lots and garages can be a significant source of CO emissions. This section summarizes the methodology used to model on-road motor vehicle emissions for the three airports. For the purposes of the emissions inventories and dispersion analyses only on-Airport vehicle trips were modeled in EDMS. It was assumed that Airport-related traffic offsite is accounted for in the regional travel demand model.

3.4.1 Emissions Factors

MOBILE5b emissions factors developed for the Clark County Department of Comprehensive Planning (Emery et al., 1999) for the Las Vegas Valley UAM applications were used in lieu of emissions factors incorporated in the EDMS database to model on-road motor vehicles. These emissions factors more accurately represent conditions in the Las Vegas metropolitan area. To account for local temperatures that occurred during the December 8-9, 1996 exceedance event, mobile source CO emissions factors were computed using the MOBILE5b model for each hour of the 20-hour modeling period. These were used to derive scaling factors to adjust the annual average emissions factors to the emission rates appropriate for the modeling episode.

Mobile source emissions factors developed by the Department of Comprehensive Planning assume a percentage of heavy duty diesel equipment in the vehicle fleet. Because airport parking areas are unlikely to accommodate heavy duty diesel vehicles, this fraction was removed and the emission factors rescaled for parking areas to reflect emissions from the remaining light-duty vehicle mix. These modified emission factors were applied to the parking areas only; all other ground access routes (including on-airport access roads) assumed the same vehicle fleet mix as used for the UAM applications.

Table 14 presents CO emissions factors, expressed in grams per mile, by vehicle speed for airport roadways and parking lots. As shown, it was assumed that emissions from on-road motor vehicles will decrease over time as the County switches to cleaner fuels and as cleaner vehicles are introduced into the fleet. This assumption is consistent with UAM assumptions.

3.4.2 Motor Vehicle Volumes – McCarran International Airport

Exhibit 1 depicts terminal area roadway segments at McCarran International Airport modeled in the 1996, 2000, 2010, and 2020 scenarios. **Exhibit 2** depicts a potential roadway scheme for the proposed eastside International Terminal. Roadway segments depicted on Exhibit 2 were modeled only in the 2010 and 2020 future year scenarios. Vehicle access on the west side of the Airport by general aviation tenants and customers, and cargo vehicle trips on Spencer Road (not shown on either exhibit) were also modeled in the EDMS.

Table 15 provides detailed information regarding each roadway segment modeled in the EDMS including: segment length, assumed annual traffic volume, and assumed vehicle speed. As noted on Exhibit 1, roadway segments 32, 52, 53, 54, 56, and 84 were modeled as parking lots in EDMS to account for vehicle dwell time at the terminal curbsides. Annual traffic volumes, and average vehicle idle times associated with the terminal curbsides and airport parking lots are summarized in **Table 16**.

Table 14

Motor Vehicle Emissions Factors – Carbon Monoxide

	Roadway CO Emissions factors (grams per mile)			
Speed (mph)	1996	2000	2010	2020
2.5	88.80	70.75	55.05	51.62
5.0	49.48	40.30	31.82	29.77
7.5	35.60	29.82	23.88	22.28
10.0	28.52	24.48	19.83	18.46
12.5	24.23	21.23	17.36	16.14
15.0	21.37	19.04	15.70	14.57
17.5	19.31	17.46	14.52	13.45
20.0	17.70	16.14	13.42	12.41
22.5	16.17	14.55	11.83	10.89
25.0	14.94	13.27	10.56	9.68
27.5	13.92	12.23	9.52	8.68
30.0	13.07	11.36	8.66	7.86
32.5	12.35	10.62	7.92	7.16
35.0	11.75	9.99	7.30	6.56
	Parking Lot CO Emissions factors (grams per mile)			
	1996	2000	2010	2020
2.5	96.99	76.00	57.42	53.44
5.0	53.16	42.70	32.72	30.36
7.5	38.10	31.46	24.39	22.58
10.0	30.57	25.83	20.21	18.67
12.5	26.07	22.46	17.70	16.32
15.0	23.10	20.22	16.03	14.76
17.5	20.99	18.62	14.84	13.65
20.0	19.30	17.24	13.73	12.60

CO = Carbon Monoxide

Source: ENVIRON, May 1999.
Prepared by: Ricondo & Associates, Inc.

Exhibit 1

Exhibit 2

Table 15

Roadway Segments Modeled in EDMS – McCarran International Airport

Segment number(a)		Segment length (miles)	Vehicle Speed	Annual Traffic Volume 1996	2000	2010	2020
1		0.08	20	365,000	432,776	662,502	1,014,172
2		0.36	20	365,000	432,776	662,502	1,014,172
3		0.08	20	1,788,500	2,120,600	0	0
4		0.09	20	803,000	952,106	0	0
5		0.09	20	803,000	952,106	0	0
6		0.13	20	803,000	952,106	0	0
7		0.04	20	803,000	952,106	0	0
8		0.13	20	803,000	952,106	0	0
10		0.08	20	803,000	952,106	0	0
11		0.04	20	803,000	952,106	0	0
12		0.10	20	985,500	1,168,494	0	0
13		0.06	20	985,500	1,168,494	0	0
14		0.12	20	985,500	1,168,494	0	0
15		0.06	10	985,500	1,168,494	0	0
16		0.05	10	985,500	1,168,494	0	0
17		0.15	20	2,956,500	3,505,482	5,366,266	8,214,796
18		0.02	20	1,788,500	2,120,600	3,246,260	4,969,444
19		0.10	30	1,095,000	1,298,327	1,987,506	3,042,517
20		0.12	30	693,500	822,273	1,258,754	1,926,927
21		0.13	30	6,898,500	8,179,457	12,521,288	19,167,857
22		0.05	30	5,365,500	6,361,800	9,738,780	14,908,333
23		0.10	30	153,300	181,766	278,251	425,952
24		0.10	30	1,533,000	1,817,657	2,782,509	4,259,524
25		0.09	30	9,709,000	11,511,829	17,622,554	26,976,983
26		0.08	30	2,263,000	2,683,208	4,107,513	6,287,868
27		0.07	30	4,964,000	5,885,747	9,010,028	13,792,743
28		0.02	30	3,650,000	4,327,755	6,625,020	10,141,723
29		0.15	30	5,584,500	6,621,465	10,136,281	15,516,836
30		0.12	30	3,403,625	4,035,632	6,177,831	9,457,157
31		0.03	30	3,403,625	4,035,632	6,177,831	9,457,157
32	(b)	0.18	--	--	--	--	--
33		0.12	15	666,125	789,815	1,209,066	1,850,864
34		0.12	15	1,168,000	1,384,882	2,120,006	3,245,351
35		0.04	20	1,606,000	1,904,212	2,915,009	4,462,358
36		0.15	15	1,587,750	1,882,573	2,881,884	4,411,650
37		0.05	20	3,358,000	3,981,535	6,095,019	9,330,385
38		0.02	15	693,500	822,273	1,258,754	1,926,927
39		0.14	15	1,587,750	1,882,573	2,881,884	4,411,650
40		0.03	20	5,721,375	6,783,756	10,384,719	15,897,151
41		0.04	25	6,086,375	7,216,532	11,047,221	16,911,323
42		0.03	30	3,951,125	4,684,795	7,171,584	10,978,415
43		0.05	30	1,204,500	1,428,159	2,186,257	3,346,769

Table 15
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Segment number(a)		Segment length (miles)	Vehicle Speed	Annual Traffic Volume 1996	2000	2010	2020
44		0.19	30	2,746,625	3,256,636	4,985,328	7,631,647
45		0.25	30	2,135,250	2,531,737	3,875,637	5,932,908
46		0.20	30	2,609,750	3,094,345	4,736,890	7,251,332
47		0.06	30	5,476,750	6,493,708	9,940,707	15,217,447
48		0.09	20	365,000	432,776	662,502	1,014,172
49		0.02	30	8,066,500	9,564,339	14,641,295	22,413,208
50		0.04	30	8,431,500	9,997,114	15,303,797	23,427,380
51		0.08	25	7,665,000	9,088,286	13,912,543	21,297,618
52	(b)	0.24	--	--	--	--	--
53	(b)	0.24	--	--	--	--	--
54	(b)	0.21	--	--	--	--	--
55		0.05	15	2,628,000	3,115,984	4,770,015	7,302,041
56	(b)	0.21	--	--	--	--	--
57		0.02	15	5,037,000	5,972,302	9,142,528	13,995,578
58		0.06	20	5,767,000	6,837,853	10,467,532	16,023,922
59		0.03	20	182,500	216,388	0	0
60		0.05	20	1,898,000	2,250,433	3,445,011	5,273,696
61		0.03	20	1,898,000	2,250,433	3,445,011	5,273,696
62		0.05	20	2,664,500	3,159,261	4,836,265	7,403,458
63		0.02	20	766,500	908,829	1,391,254	2,129,762
64		0.33	20	766,500	908,829	1,391,254	2,129,762
65		0.23	30	2,080,500	2,466,820	3,776,262	5,780,782
66		0.07	30	2,080,500	2,466,820	3,776,262	5,780,782
67		0.02	30	777,450	921,812	1,411,129	2,160,187
68		0.03	30	1,303,050	1,545,009	2,365,132	3,620,595
69		0.06	20	1,554,900	1,843,624	2,822,259	4,320,374
70		0.03	20	777,450	921,812	1,411,129	2,160,187
71		0.06	20	2,080,500	2,466,820	3,776,262	5,780,782
72		0.09	30	730,000	865,551	1,325,004	2,028,345
73		0.06	30	1,715,500	2,034,045	3,113,760	4,766,610
74		0.08	25	365,000	432,776	662,502	1,014,172
75		0.06	25	2,737,500	3,245,816	4,968,765	7,606,292
76		0.04	30	2,445,500	2,899,596	4,438,764	6,794,954
77		0.08	15	2,965,625	3,516,301	5,382,829	8,240,150
78		0.19	15	693,500	822,273	1,258,754	1,926,927
79		0.09	20	2,272,125	2,694,028	4,124,075	6,313,223
80		0.15	20	1,606,000	1,904,212	2,915,009	4,462,358
81		0.08	20	666,125	789,815	1,209,066	1,850,864
82	(c)	0.26	20	292,000	346,220	530,002	811,338
83	(c)	0.37	20	1,277,500	1,514,714	2,318,757	3,549,603
84	(b)	--	--	--	--	--	--
91	(d)	0.04	20	0	0	1,788,155	2,738,265
92	(d)	0.02	20	0	0	1,931,855	2,957,326
93	(d)	0.02	20	0	0	1,609,880	2,464,439

Table 15
(Page 3 of 3)

Segment number(a)		Segment length (miles)	Vehicle Speed	Annual Traffic Volume 1996	2000	2010	2020
94	(d)	0.05	15	0	0	321,975	492,887
95	(d)	0.01	15	0	0	321,975	492,887
96	(d)	0.01	15	0	0	321,975	492,887
97	(d)	0.05	20	0	0	321,975	492,887
98	(d)	0.05	15	0	0	1,287,905	1,971,552
99	(b)(d)	--	--	--	--	--	--
100	(d)	0.22	15	0	0	35,775	54,765
101	(d)	0.07	20	0	0	447,188	684,565
102	(d)	0.02	20	0	0	447,188	684,565
103	(d)	0.06	20	0	0	804,942	1,232,222
104	(d)	0.04	20	0	0	804,942	1,232,222
105	(d)	0.04	20	0	0	804,942	1,232,222
106	(d)	0.10	15	0	0	804,942	1,232,222
107	(d)	0.09	20	0	0	1,126,917	1,725,109
108	(d)	0.05	20	0	0	1,126,917	1,725,109
109	(d)	0.02	15	0	0	143,100	219,061
110	(d)	0.04	20	0	0	983,817	1,506,048
111	(d)	0.03	15	0	0	321,975	492,887
112	(d)	0.01	15	0	0	321,975	492,887

(a) See Exhibit 1.
(b) Roadway segments 32, 52, 53, 54, 56, 84, and 99 modeled as parking lots to account for dwell time at the curbside.
(c) Not shown on Exhibit 1.
(d) Roadway network associated with the future eastside international terminal facility (Exhibit 2).

Source: Ricondo & Associates, Inc. based on information obtained from the Clark County Department of Aviation and the FAA's Terminal Area Forecast for McCarran International Airport.
Prepared by: Ricondo & Associates, Inc.

Table 16

Parking Lot and Curbside Traffic Volumes – McCarran International Airport

Lot Name	Type (a)	Idle time (minutes)	Annual Traffic Volume 1996	2000	2010	2020
Silver Garage	Short term	1.5	1,587,750	1,882,573	2,881,884	4,411,650
Gold Garage	Long term	1.5	666,125	789,815	1,209,066	1,850,864
Oversize Surface	Employee	1.5	1,606,000	1,904,212	2,915,009	4,462,358
West Side	Westside parking	1.5	292,000	346,220	530,002	811,338
Spencer	Air cargo parking	1.5	1,277,500	1,514,714	2,318,757	3,549,603
West Departure	Departure curbside	2.8	4,307,000	5,106,751	7,817,524	11,967,233
East Departure	Departure curbside	2.8	1,058,500	1,255,049	1,921,256	2,941,100
Courtesy	Courtesy curbside	3.3	949,000	1,125,216	1,722,505	2,636,848
Taxi	Taxi curbside	3.5	2,007,500	2,380,265	3,643,761	5,577,948
Arrival	Arrival curbside	3	1,241,000	1,471,437	2,252,507	3,448,186
Zero Level	Group movements	3.5	839,500	995,384	1,523,755	2,332,596
International (b)	Curbside	1.7	--	--	1,287,905	1,971,552
International (b)	Public Parking	1.5	--	--	321,975	492,887
International (b)	Employee Parking	1.5	--	--	321,975	492,887

(a) Terminal curbsides were modeled as parking lots
(b) Future eastside International terminal.

Source: Ricondo & Associates, Inc. based on information obtained from the Clark County Department of Aviation.
Prepared by: Ricondo & Associates, Inc.

Annual traffic counts for on-Airport roadways and parking lots at McCarran International Airport for 1996 were derived from the study *Air Pollutant Emissions Inventory McCarran International, North Las Vegas, and Henderson Executive Airports*. Forecasts of future year traffic volumes were developed by Ricondo & Associates, Inc. and assume an average annual growth rate of 4.35%, consistent with the FAA's Terminal Area Forecast for McCarran International Airport (forecast growth in enplanements).

3.4.3 Motor Vehicle Volumes – North Las Vegas and Henderson Executive Airport

Airport roadway segments and parking lots at North Las Vegas Airport and Henderson Executive Airport were also modeled in the EDMS. Counts of on-road motor vehicle trips in 1996, 2000, 2010, and 2020 at North Las Vegas airport and Henderson Executive airport are summarized in **Tables 17 and 18**, respectively. Tables 17 and 18 also summarize traffic volumes associated with parking lots at each airport.

As discussed in the table notes, vehicle trips associated with general aviation tenants and commercial (air tour) tenants were estimated separately. Roadway traffic volumes and assumed vehicle operating speeds in 1996 for both facilities are based on information contained in the *Air Pollutant Emissions Inventory McCarran International, North Las Vegas, and Henderson Executive Airports.* Future year motor vehicle traffic volumes at North Las Vegas Airport are based on (1) forecast growth in aircraft operations and (2) an average annual growth rate of 5.51% in air tour passengers. Future year motor vehicle traffic volumes at Henderson Executive Airport are similarly based on forecast growth in aircraft operations and growth in the number of air tour passengers (assumed to be 4.98% annually).

3.5 Airport Construction Activity

Numerous capital improvement projects are planned at airports controlled by Clark County. To ensure that the future year airport CO emissions inventories and the related dispersion analyses appropriately reflected CO emissions, many of these projects were modeled in EDMS. **Table 19** summarizes major runway and terminal projects planned at each of the three airports and the approximate timing of these developments based on consultation with Department of Aviation staff.

Table 17
Motor Vehicle Traffic Volumes – North Las Vegas Airport

	Year			
	1996	**2000**	**2010**	**2020**
Average daily air tour passengers	588 (a)	926	1,585	2,709
Average daily aircraft operations	725 (a)	918	965	1,014
Vehicle trip ends per day				
Generated by air tour passengers				
Air tour 1 (b)	78	123	211	361
Air tour 2 (c)	14	22	38	65
Total	92	145	249	426
Generated by aircraft operations (d)	1,878	2,377	2,499	2,626
Total daily vehicle trips	1,970	2,522	2,748	3,052
Annual traffic volume	719,050	920,530	1,003,020	1,113,980

(a) Provided by the Clark County Department of Aviation
(b) Air tour 1 assumed to consist of 75% of total daily passengers.
Assumes 15 seats per bus with a 75% load factor.
(c) Air tour 2 assumed to consist of 25% of total daily passengers.
Assumes 30 seats per bus with a 70% load factor.
(d) Using a ratio of 2.59 vehicle trip ends per aircraft operation.

Source: Ricondo & Associates, Inc. based on information contained in *Air Pollutant Emissions Inventory, McCarran International, North Las Vegas, and Henderson Executive Airport*s
Prepared by: Ricondo & Associates, Inc.

Table 18

Motor Vehicle Traffic Volumes – Henderson Executive Airport

	Year			
	1996	**2000**	**2010**	**2020**
Average daily air tour passengers	293 (a)	302	491	798
Average daily aircraft operations	159 (a)	214	309	445
Vehicle trip ends per day				
Generated by air tour passengers				
Air tour 1 (b)	13	13	22	35
Air tour 2 (c)	16	16	26	43
Total	29	29	48	78
Generated by aircraft operations (d)	412	554	800	1,153
Total daily vehicle trips	441	583	848	1,231
Annual traffic volume	160,965	212,795	309,520	449,315

(a) Provided by the Clark County Department of Aviation.
(b) Air tour 1 assumed to consist of 20% of total daily passengers. Assumes 15 seats per bus with a 60% load factor.
(c) Air tour 2 assumed to consist of 80% of total daily passengers. Assumes 30 seats per bus with a 60% load factor.
(d) Using a ratio of 2.59 vehicle trip ends per aircraft operation.

Source: Ricondo & Associates, Inc. based on information contained in *Air Pollutant Emissions Inventory, McCarran International, North Las Vegas, and Henderson Executive Airport*s

Prepared by: Ricondo & Associates, Inc.

Table 19

Future Airport Construction Activity – Clark County Airport System

Airport	Project	Year (a)
McCarran International Airport	Concourse D Phase I (b)	2000
	Runway 1L-19R reconstruction (b)	2000
	Concourse D Phase II	2010
	International Terminal/Unit Terminal	2010
	International Terminal roadway	2010
North Las Vegas Airport	Carey Avenue hangar project	2010
	Runway 12L-30R construction	2010
	East-side basing area	2010
Henderson Executive Airport	Runway 17R-35L	2010
	Runway 17L-35R	2010
	New terminal facilities	2010

(a) EDMS modeling year the project would be in place.
(b) Completed since 1996 CO exceedance event.

Source: Clark County Department of Aviation.
Prepared by: Ricondo & Associates, Inc.

IV. EMISSIONS INVENTORIES

The EDMS was used to calculate airport-related emissions of carbon monoxide (CO) for 1996, 2000, 2010, and 2020. **Table 20** summarizes the annual emissions inventories conducted for McCarran International, North Las Vegas, and Henderson Executive airports.

As shown in the Table 20, CO emissions at the three airports are predominantly a result of aircraft and GSE activity. As noted earlier, on-road motor vehicle emissions in these inventories only include on-airport roadways and parking facilities.

Table 20
Airport-Related CO Emissions – Tons Per Year

McCarran International Airport

Source	1996	2000	2010	2020
Aircraft	3,515.37	3,807.44	6,330.75	10,056.60
GSE/APU	6,044.82	6,565.15	8,891.72	12,014.42
Roadways	237.67	254.99	293.89	409.37
Parking Lots	219.10	210.33	251.67	355.74
Stationary Sources	4.91	0.71	0.71	0.71
Total	10,021.88	10,842.81	15,772.93	22,845.24

North Las Vegas Airport

Source	1996	2000	2010	2020
Aircraft	2,652.25	3,110.38	3,388.04	3,712.83
GSE/APU	66.28	81.70	88.27	92.78
Roadways	3.18	3.57	3.17	3.23
Parking Lots	5.60	5.69	4.71	4.86
Stationary Sources	0.03	0.03	0.03	0.03
Total	2,727.33	3,201.37	3,484.21	3,813.73

Henderson Executive Airport

Source	1996	2000	2010	2020
Aircraft	475.85	642.53	924.13	1,328.98
GSE/APU	56.89	76.82	110.48	158.88
Roadways	1.87	2.21	2.56	3.41
Parking Lots	1.49	1.58	1.75	2.35
Stationary Sources	0.00	0.00	0.00	0.00
Total	536.10	723.14	1,038.92	1,493.61

GSE = Ground Service Equipment
APU = Auxiliary Power Unit

Source: Ricondo & Associates, Inc.
Prepared by: Ricondo & Associates, Inc.

V. AIR QUALITY DISPERSION ANALYSES

Dispersion modeling using EDMS is significantly more complex in scope and in data input requirements than emissions inventory modeling. Users must (1) specify coordinates for sources of emissions, (2) assign aircraft to runways, runway queues, taxiways, and gate areas, (3) develop appropriate operational profiles for mobile sources, (4) develop weather variables for individual hours, and (5) define other source-specific parameters for each emissions source included in the dispersion analysis. The user is also required to define individual receptors or grids of receptors for pollutant concentration estimation. In preparing for the dispersion analyses, airport operations and physical planning data were assembled and documented for all three airports under consideration.

The methodology followed, and key assumptions used for the dispersion modeling aspect of the study are described in the sections that follow.

5.1 Coordinates of Pollutant Sources

Coordinates for major point (e.g., boilers and passenger gates), area (e.g., parking lots), and line (e.g., roads, taxiways and runways) sources of CO pollutant emissions were derived from Airport Layout Plans (ALPs) provided by the Clark County Department of Aviation. The ALPs plans provide configurations, lengths, and coordinates of runway and taxiways, commercial aircraft gates, and other airport facilities (boilers, generators, etc.) that are sources of CO emissions.

5.2 Airport Operational Profiles

Atmospheric dispersion of pollutants in EDMS is calculated for one hour periods. Because sources of CO emissions at airports vary in their activity or strength depending on the hour of the day, EDMS allows users to develop operational profiles to simulate variations in airport-related traffic volumes that occur over the course of an entire year (8760 hours). These operational profiles can be used to define hourly, daily, and monthly peaking characteristics for aircraft and ground access vehicles.

Operational profiles were defined for aircraft, ground access vehicles, and ground support equipment on the basis of available data, including airline schedules, and FAA records. To match conditions that were present during the December 8-9, 1996 exceedance episode, operations data from the month of December were selected instead of data from March or October which are typically the busiest months of the year at the Airport in terms of total aircraft operations. Data used to develop aircraft operational profiles included: (1) monthly operations summaries by aircraft type; (2) daily operations summaries for the month of December; and (3) hourly operations summaries for an average day in December.

5.3 Aircraft Runway Assignments

The EDMS dispersion module requires runway, taxiway, and gate assignments for each active aircraft in the study. These assignments directly affect emissions concentrations and therefore are a crucial component of EDMS dispersion modeling. **Table 21** summarizes assumed baseline (1996) and future year departure runway use percentages by aircraft type for McCarran International Airport. Similar information for North Las Vegas Airport is presented in **Table 22**.

Table 21
Departure Runway Use –- McCarran International Airport

1996 Runway Use - Aircraft Departures

	Runway		
Aircraft Category	**19L**	**19R**	**25R**
Air Carrier (a)(b)	55.0%	0.0%	45.0%
Air Taxi	55.0%	0.0%	45.0%
General Aviation(b)	0.0%	100.0%	0.0%
Military (c)	0.0%	100.0%	0.0%

2000, 2010, 2020 Runway Use - Aircraft Departures

	Runway		
Aircraft Category	**19L**	**19R**	**25R**
Air Carrier (a)(b)	35.0%	15.0%	50.0%
Air Taxi	35.0%	15.0%	50.0%
General Aviation(b)	0.0%	100.0%	0.0%
Military (c)	0.0%	100.0%	0.0%

(a) It was assumed that all operations based at the Cargo area depart on Runway 25R.
(b) It was assumed that operations based at the Terminal 2 use Runways 25R or 19L.
(c) It was assumed that all operations originating at the EG&G facility use 19L for departure.

Source: Ricondo & Associates, Inc. based on information provided by the Clark County Department of Aviation and contained in the Federal Aviation Administration's report *Capacity Enhancement Plan, Las Vegas McCarran International Airport*.
Prepared by: Ricondo & Associates, Inc.

Table 22

Departure Runway Use –– North Las Vegas Airport

	1996 and 2000 Runway Use - Aircraft Departures			
	Runway			
Aircraft Category	**7**	**25**	**12**	**30**
Air Taxi	25.0%	0.0%	75.0%	0.0%
GA-heavy	60.0%	0.0%	40.0%	0.0%
GA-light	60.0%	0.0%	40.0%	0.0%

	2010 and 2020 Runway Use - Aircraft Departures			
	Runway			
Aircraft Category	**7**	**25**	**12R**	**12L**
Air Taxi	25.0%	0.0%	75.0%	0.0%
GA-heavy	60.0%	0.0%	40.0%	0.0%
GA-light	10.0%	0.0%	80.0%	10.0%

GA = General Aviation

Note: Runway 12-30 will be redesignated 12R-30 left after Runway 12L-30R is constructed.

Source: Ricondo & Associates, Inc. based on information contained in the report *Final Environmental Assessment, Proposed Runway 12L-30R, North Las Vegas Airport*.

Prepared by: Ricondo & Associates, Inc.

For Henderson Executive Airport it was assumed that all aircraft would depart to the north. In 2010 and 2020 – following the construction of Runways 17R-35L and 17L-35R – it was assumed that all non-training flights will depart on Runway 35L and all training operations will depart on Runway 35R.

The assignment of aircraft to airport runways at McCarran International Airport was based on information contained in the Federal Aviation Administration's *Las Vegas McCarran International Airport, Capacity Enhancement Plan* and confirmed through an analysis of ten years of meteorological data obtained from the National Climatic Data Center. Runway end assignments at North Las Vegas Airport and Henderson Executive Airport were based on information contained in environmental assessments cited earlier in this report.

5.4 Aircraft Gate Assignments

The following paragraphs summarize the approach used to assign aircraft to gate areas at the three Clark County Airports.

- The assignment of aircraft to passenger gate areas at McCarran International Airport was accomplished through a review of (1) aircraft landings data maintained by the Department of Aviation, and (2) existing and historical (1996) airline gate assignments. A total of eight gate areas were modeled in the 1996 dispersion scenario; nine gate areas were modeled in the 2000, 2010, and 2020 modeling scenarios. The additional gate area used for 2000, 2010, and 2020, reflects the opening of Concourse D in 1998. By 2010 it is assumed that Terminal 2 will be closed and that all international operations will be relocated to an eastside terminal facility north of Concourse D.

- Gate assignments at North Las Vegas Airport were based on a review of aircraft landings data. Three gate areas were modeled at North Las Vegas for the 1996 and 2000 modeling scenarios. It was assumed that an eastside basing area would be constructed at North Las Vegas prior to 2010.

- At Henderson Executive Airport one gate area was modeled in EDMS.

5.5 Meteorological Data

The EDMS uses five weather parameters in its dispersion modeling: temperature, wind speed, wind direction, Pasquill-Gifford Stability classification, and mixing height. Meteorological data used in the dispersion modeling included National Weather Service hourly surface data from McCarran International Airport, and weather data contained in the County's UAM database for the exceedance episode.

The hourly meteorological data observations taken at McCarran International Airport include winds and temperature. Meteorological observation data are not available from North Las Vegas and Henderson Executive airports, therefore wind data from the Urban Airshed Model input database were extracted for these locations for use in EDMS. Temperatures recorded at McCarran International Airport were used for all three airports. Hourly mixing height and stability measures were also based on the UAM input database, and were assumed to be spatially constant. Weather information used for the 20-hour exceedance episode is presented in **Table 23**.

Table 23

Meteorological Data –- CO Dispersion Analyses

	McCarran International		North Las Vegas		Henderson Executive			
Hour	Wind (kts)	Direction	Wind (kts)	Direction	Wind (kts)	Direction	Temperature (^{o}C)	PGT
15	0	100	2	140	1	70	17	2
16	0	150	2	180	0	220	17	5
17	0	190	2	240	2	250	16	6
18	5	250	2	250	2	230	13	6
19	7	250	2	310	2	250	11	6
20	6	260	2	350	2	270	11	6
21	3	220	1	350	1	210	10	6
22	4	200	0	310	1	250	9	6
23	4	240	1	300	1	200	9	6
0	6	250	2	320	2	200	8	6
1	4	220	1	320	2	220	7	6
2	5	270	2	310	3	210	7	6
3	7	250	2	320	3	210	7	6
4	4	220	2	320	3	230	7	6
5	3	230	2	350	2	210	6	6
6	6	250	1	310	2	220	6	6
7	4	220	2	320	2	240	7	6
8	0	230	1	350	1	220	8	5
9	0	130	1	140	1	150	9	3
10	0	140	0	170	0	200	11	2

PGT = Pasquill-Gifford Stability classification. This classification describes the level of atmospheric stability (i.e., the ability of the atmosphere to dilute and mix air). The PGT has six ranges (1-6) which signify very unstable (1) to stable (6) conditions.

Source: ENVIRON.
Prepared by: Ricondo & Associates, Inc.

5.6 Grid Receptors

In the Urban Airshed Model, the Las Vegas Valley is represented by a grid of 2,500 one-kilometer grids cells (50x50 grid) for emissions and dispersion estimation. To accurately measure airport-related CO concentrations in EDMS, a more refined grid of receptors was established for each airport. Each set of grid receptors was designed to subdivide and directly overlay the one-kilometer UAM grid. The EDMS grid resolution and the overall extent of the receptor grid for each airport was determined by running the UAM with and without airport emissions and comparing the resulting UAM CO concentration patterns. A receptor grid spacing of 250 meters was determined to adequately resolve the structure of the resulting dispersion pattern from the various airport sources. Based on the UAM results, it was necessary to define a rather expansive receptor grid for McCarran so that the full extent of the airport's CO concentration "footprint" (to 0.1 ppm) would be modeled with EDMS. The number of EDMS receptors defined for each airport is as follows:

McCarran: 2501 (15x10 km)
North Las Vegas: 825 (8x6 km)
Henderson Executive: 221 (4x3 km)

VI. EDMS DISPERSION MODELING RESULTS

The ten highest[1] 8-hour average CO concentrations estimated by the EDMS for each modeling year are presented in **Tables 24, 25, and 26** for McCarran International, North Las Vegas, and Henderson Executive airports respectively. As shown in the tables, EDMS-estimated CO concentrations are below the EPA's National Ambient Air Quality Standards (NAAQS) primary 8-hour standard for CO in all four modeling years.

The rank-ordered 8-hour CO concentrations are expressed in parts per million (ppm) and assume no new County mandated emissions reduction controls on on-road motor vehicles beyond those previously adopted and currently in place. The "period" indicates the hour range of maximum CO concentrations expressed in military time.

From these results it appears that only CO emissions at McCarran International Airport may be of concern to the County. While no airport receptor recorded an exceedance of the primary 8-hour standard for CO, CO concentrations in the northwest quadrant of McCarran International Airport particularly in the vicinity of Runway 19R (Receptor 469) were significantly higher than those recorded at North Las Vegas and Henderson Executive airports. In addition, it is noted that between 1996 and 2020 a shift in the timing of the highest CO concentrations occurs from a dominance in the late evening (4 PM to 12 midnight) in 1996 to more peaks during the following morning (2 AM to 10 AM) in 2010 and 2020.

[1] Complete results of the EDMS dispersion modeling were reviewed by Department of Aviation staff and imported into the Department's Geographic Information System (GIS).

Table 24

8-Hour Average CO Concentrations –- McCarran International Airport

1996 Base			2000 Base			2010 Base			2020 Base		
Receptor	Period	CO	Receptor	Period	CO	Receptor	Period	CO	Receptor	Period	CO
470	15-23	3.00	470	15-23	2.30	469	01-09	5.61	469	01-09	6.26
470	16-24	2.84	470	16-24	2.17	469	03-11	4.96	469	03-11	5.58
511	18-02	2.33	511	18-02	1.73	469	02-10	4.92	469	02-10	5.52
511	17-01	2.32	511	17-01	1.72	469	00-08	4.17	469	00-08	4.65
470	03-11	1.94	470	03-11	1.54	469	21-05	3.97	469	21-05	4.42
511	16-24	1.92	511	16-24	1.51	469	23-07	3.62	469	23-07	4.03
511	19-03	1.64	629	16-24	1.44	469	22-06	3.46	469	22-06	3.85
511	15-23	1.61	629	17-01	1.42	469	18-02	3.42	469	18-02	3.81
470	17-01	1.61	629	15-23	1.40	469	19-03	3.38	469	19-03	3.77
511	23-07	1.46	511	15-23	1.29	469	20-04	3.21	469	20-04	3.58

Source: Emissions and Dispersion Modeling System (EDMS).
Prepared by: Ricondo & Associates, Inc.

Table 25

8-Hour Average CO Concentrations –- North Las Vegas Airport

1996 Base			2000 Base			2010 Base			2020 Base		
Receptor	Period	CO	Receptor	Period	CO	Receptor	Period	CO	Receptor	Period	CO
268	15-23	0.42	316	03-11	0.39	268	15-23	0.55	316	03-11	0.51
268	16-24	0.37	292	03-11	0.38	268	16-24	0.49	292	03-11	0.50
292	03-11	0.36	316	02-10	0.37	292	03-11	0.46	316	02-10	0.50
292	02-10	0.34	292	02-10	0.37	316	03-11	0.45	292	02-10	0.49
316	03-11	0.34	268	15-23	0.37	292	02-10	0.45	268	15-23	0.45
316	02-10	0.33	268	16-24	0.33	316	02-10	0.44	268	03-11	0.45
268	17-01	0.33	316	01-09	0.33	268	17-01	0.43	316	01-09	0.44
316	01-09	0.29	268	03-11	0.32	316	01-09	0.38	268	02-10	0.42
292	01-09	0.28	292	01-09	0.30	292	01-09	0.37	268	16-24	0.40
316	00-08	0.25	268	17-01	0.30	268	03-11	0.34	292	01-09	0.40

Source: Emissions and Dispersion Modeling System (EDMS).
Prepared by: Ricondo & Associates, Inc.

Table 26

8-Hour Average CO Concentrations –- Henderson Executive Airport

1996 Base			2000 Base			2010 Base			2020 Base		
Receptor	Period	CO	Receptor	Period	CO	Receptor	Period	CO	Receptor	Period	CO
92	15-23	0.14	92	15-23	0.19	89	15-23	0.14	89	15-23	0.20
92	16-24	0.11	92	16-24	0.19	89	16-24	0.14	89	16-24	0.20
92	03-11	0.11	92	03-11	0.14	181	15-23	0.08	107	15-23	0.10
91	15-23	0.09	91	15-23	0.12	181	16-24	0.08	107	16-24	0.10
91	16-24	0.09	91	16-24	0.12	107	15-23	0.07	146	15-23	0.10
91	17-01	0.09	91	17-01	0.12	107	16-24	0.07	146	16-24	0.10
93	03-11	0.06	93	03-11	0.08	181	17-01	0.07	198	15-23	0.10
93	15-23	0.06	93	15-23	0.08	168	15-23	0.05	198	16-24	0.10
93	16-24	0.05	93	16-24	0.07	168	16-24	0.05	146	17-01	0.10
110	15-23	0.04	110	15-23	0.06	198	15-23	0.05	131	15-23	0.09

Source: Emissions and Dispersion Modeling System (EDMS).
Prepared by: Ricondo & Associates, Inc.

VII. REFERENCES

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8. SABRE Decision Technologies. *Las Vegas McCarran International Airport Curbside Traffic Simulation Study*. October 1996.