MAG AIR QUALITY MODELING PROGRAM

In accordance with the Clean Air Act, modeling analyses must be performed to demonstrate attainment and maintenance of the federal air quality standards and to evaluate the effectiveness of control measures. Regional air quality modeling work is conducted by MAG for carbon monoxide, ozone, and particulate matter.

The modeling process involves a broad range of technical processes and research, including development of emissions inventories, validation of modeling procedures, and simulation of future air quality conditions. Air quality modeling analyses must also be performed to determine the conformity of transportation plans, programs, and projects. Conformity analyses have been performed since the requirements of the 1990 Clean Air Act Amendments took effect.

It is necessary to maintain, update, and enhance the air quality models for the determination of conformity and for the preparation of the regional air quality plans. Effectively maintained, updated, and enhanced models produce essential data regarding the pollution problems in the Maricopa County area and facilitate effective regional air quality planning.

The MAG air quality modeling staff downloads and installs, runs, and validates emissions, meteorology, and air quality models developed by the U.S. Environmental Protection Agency (EPA), Federal Aviation Administration (FAA), National Center for Atmospheric Research (NCAR) for MAG air quality and emission modeling analyses, and also develops models, tools, and utilities (e.g., M6LINK, MOVESLINK, MOVESLINK2014, Modeling Request System, Performance Evaluation of Air Quality Simulation Tool) for air quality modeling research.

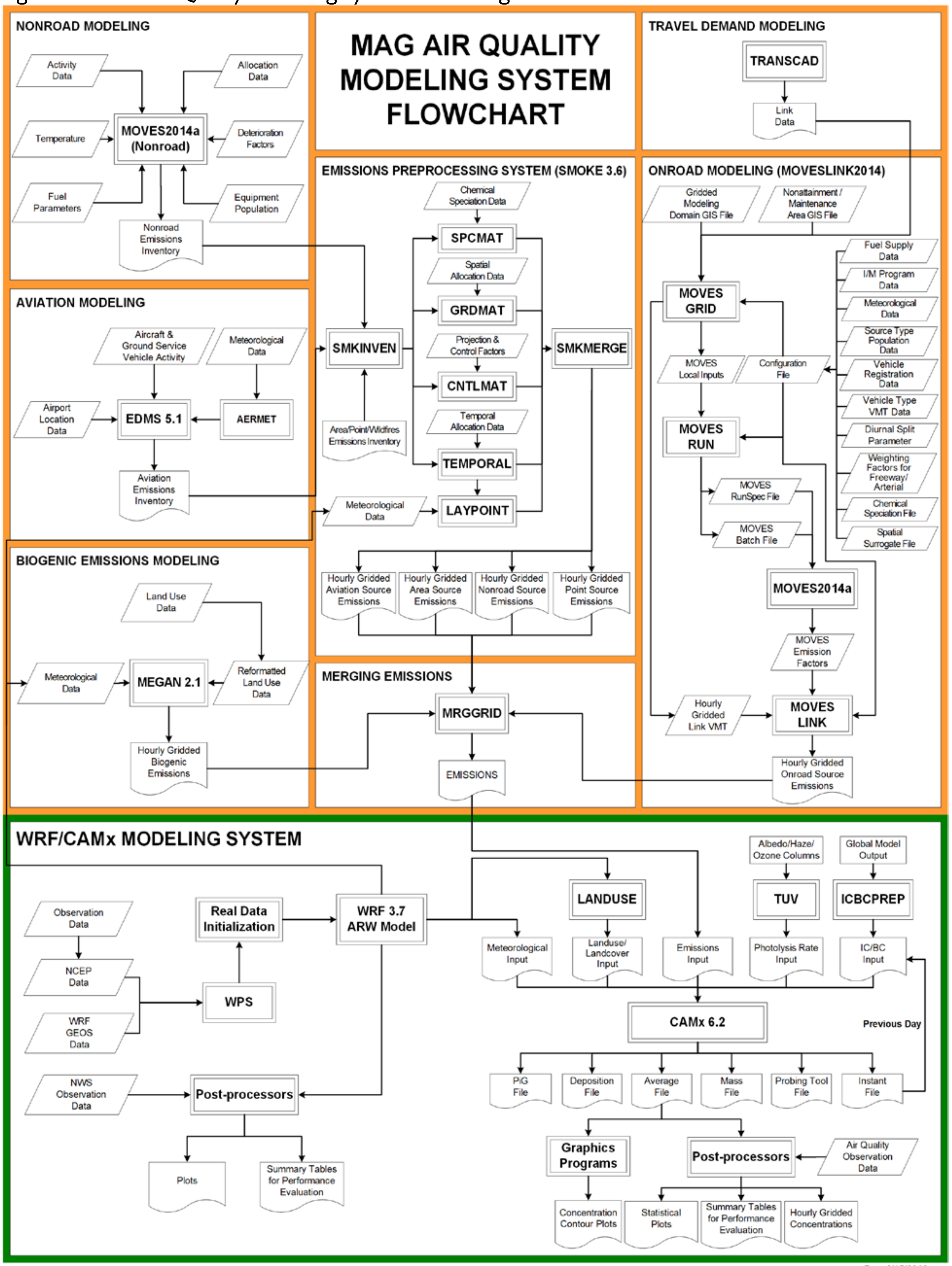
Figure 1 presents the MAG air quality modeling system flow diagram to perform air quality modeling analyses and research. The models are described below.

Motor Vehicle Emission Simulator 2014a

The Motor Vehicle Emissions Simulator 2014a (MOVES2014a) is the EPA state-of-the-art tool for estimating emissions from on-road mobile sources. The model is based on analyses of millions of emission test results and considerable advances in understanding of vehicle emissions. MOVES2014a is the latest version of the EPA's MOVES emissions modeling tool for use in the development of a State Implementation Plan (SIP), regional conformity analysis, and emissions inventory. MOVES2014a requires a detailed level of local data such as fuel data, the Inspection/Maintenance (I/M) Program data, meteorological data, vehicle registration data, annual vehicle miles traveled (VMT), monthly/daily/hourly VMT fractions, road type distribution, average speed distribution, and ramp fraction.

The MAG air quality modeling staff utilizes MOVES2014a to conduct the regional conformity analysis, prepare the national/periodic emissions inventory for on-road mobile sources, develop on-road mobile source emissions for air quality models for ozone, carbon monoxide (CO), and particulate matter (PM-10 and PM-2.5) SIPs, provide emission rates for hot-spot analysis, and evaluate the Congestion Mitigation and Air Quality Improvement Projects.

Figure 1 MAG Air Quality Modeling System Flow Diagram



MAG Onroad Mobile Source Emissions Processing Model

MOVESLINK2014 was developed by the MAG air quality modeling staff to interface with the EPA MOVES2014a on-road vehicle emissions model. MAG uses MOVESLINK2014 to derive air quality model on-road emissions inputs and pollutant emissions totals for regional transportation conformity analyses. MOVESLINK2014 is written in the Python language and interacts with MOVES2014a, ArcGIS, and MySQL programs to: (1) Calculate link activity data (e.g., ramp factions, and link vehicle speeds and VMTs by road type, vehicle type, and area type) from Travel Demand Model network outputs, (2) Implement the MOVES2014a executable program to calculate emissions rates using link activity data, (3) Calculate link emissions and off-network emissions, and (4) Develop County and sub-County level onroad and off-network emissions for the regional transportation conformity analysis or hourly gridded and chemically speciated onroad mobile source emissions for photochemical air quality modeling analysis.

MOVESLINK2014 is designed to go through three successive stages: MOVESGRID, MOVESRUN and MOVESLINK. MOVESGRID uses travel demand model outputs, GIS shape files, fuel data, I/M program data, meteorological data, source type population, vehicle type VMT, vehicle registration data, and alternative vehicle fuels and technologies (AVFT) data to prepare required local input files for a MOVES2014a run. MOVESRUN executes MOVES2014a using the local input data prepared by MOVESGRID and generates MySQL input/output databases for the MOVES2014a run. MOVESLINK calculates total pollutant emissions for a modeling area as the last stage.

Nonroad Mobile Source Emissions Model

MOVES2014a nonroad is the major update of the EPA NONROAD model and it supersedes all previous versions of this model, most recently NONROAD2008. It calculates past, present, and future emission inventories (i.e., tons of pollutant) for all nonroad equipment categories except commercial marine, locomotives, and aircraft. Fuel types included in the model are: gasoline, diesel, compressed natural gas, and liquefied petroleum gas. The model estimates exhaust and evaporative hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NOx), particulate matter (PM), sulfur dioxide (SO_2), and carbon dioxide (CO_2). The user may select a specific geographic area (i.e., national, state, or county) and time period (i.e., annual, monthly, seasonal, or daily) for analysis.

The MAG air quality modeling staff uses the model in calculating nonroad emissions of ozone precursors and particulate matter for the Periodic Emissions Inventory for ozone, carbon monoxide, and PM-10 as well as for photochemical modeling in State Implementation Plans. The model is used to estimate nonroad equipment emissions for both Maricopa and Pinal Counties, utilizing local fuel data and meteorology as inputs to derive region-specific emissions for agricultural equipment, commercial equipment industrial equipment, construction/mining equipment, lawn and garden equipment, pleasure water craft, railway maintenance equipment and recreational vehicles.

Emissions and Dispersion Modeling System

The Emissions and Dispersion Modeling System (EDMS) model was developed by the Federal Aviation Administration (FAA). The model has been used to develop airport emissions for aircraft, auxiliary power units (APUs), and ground support equipment (GSE). This model is also designed to assess the air quality impacts of airport emission sources. The latest EDMS 5.1.4 features up-to-date aircraft engine emission factors from the International Civil Aviation Organization (ICAO) Engine Exhaust Emissions Data Bank. The EDMS model computes air pollutant emissions such as total hydrocarbons (THC), non-methane hydrocarbons (NMHC), volatile organic compounds (VOC), carbon dioxide (CO_2), carbon monoxide (CO), oxides of nitrogen (NOx), and particulates (PM-10 and PM-2.5). Inputs to EDMS include aircraft activity in terms of operations or Landing and Taking-Off (LTO) cycles, aircraft fleet mix, monthly/weekly/daily profiles, and meteorological data from surface and upper air stations.

The MAG air quality modeling staff develops airport emissions in Maricopa County and Pinal County using the EDMS model for the State Implementation Plans (SIP) and Periodic Emissions Inventory for ozone precursors, carbon monoxide, and PM-10.

Model of Emissions of Gases and Aerosols from Nature

The Model of Emissions of Gases and Aerosols from Nature (MEGAN) is a biogenic source modeling system for estimating emissions of gases and aerosols from terrestrial ecosystems. Driving variables include land use and land cover, WRF meteorological data, and atmospheric chemical composition. Meteorological data are developed using meteorological observational datasets by the WRF model. The meteorological input data such as temperature, humidity, wind speed, and solar radiation govern temporal variability of vegetation and soil emissions. Leaf area index (LAI) and plant function types (PFT) are also important to develop geospatial vegetation emissions. The MAG air quality modeling staff utilizes the MEGAN model to develop the biogenic emissions inventory for the photochemical air quality modeling analysis and the Periodic Emissions Inventory for ozone precursors.

Weather Research and Forecasting Meteorology Model

The Weather Research and Forecasting (WRF) model is a next generation mesoscale numerical weather prediction system designed for both atmospheric research and operational forecasting needs. The addition of capabilities to the WRF model is particularly important for air quality modeling applications. The MAG air quality modeling staff uses the WRF model to simulate three-dimensional meteorological fields to predict air quality in the region with CMAQ and CAMx photochemical air quality models, and to provide meteorological modeling input data for emission models such as SMOKE, EDMS and MEGAN.

The MAG air quality modeling staff takes advantage of the WRF model to determine how weather conditions affect air quality in the Valley. Initial and boundary conditions for the continental North America are needed for running the WRF model. The Initial and boundary conditions data are developed by the WRF Preprocessing System (WPS) based upon outputs from the National Centers for Environmental Prediction (NCEP) Eta regional weather model. This model covers a larger extent over the Northern Hemisphere, with 40 km grid spacing on a standard '212 grid'. Data for this model are downloaded from the National Center for Atmospheric Research (NCAR) Computational Information Systems Laboratory (CISL) research data archives. The WPS provides the data for the WRF simulations at a standard 3-hour interval.

Sparse Matrix Operator Kernel Emissions Modeling System

The Sparse Matrix Operator Kernel Emissions (SMOKE) is the emission processing system designed to convert the emissions inventory to gridded, speciated, and temporally processed emissions so that these emissions can be used as inputs for air quality models, such as the EPA's regulatory Community Multi-scale Air Quality (CMAQ) model and the Comprehensive Air Quality Model with Extensions (CAMx). These air quality models are important to federal and state agencies for management of healthy air quality levels in the United States. These agencies, such as EPA, Western Regional Air Partnership's (WRAP), Northeast States for Coordinated Air Use Management (NESCAUM), Mid-Atlantic Regional Air Management Association (MARAMA) and California Air Resources Board (CARB), use the models since they are tasked with controlling air pollution by identifying pollution sources and designing effective strategies to reduce harmful air pollutants aiming at attaining National Ambient Air Quality Standards (NAAQS) across the country. Both the CMAQ and CAMx models simulate the pollutant impacts by estimating concentrations of pollutants over large spatial scales.

The SMOKE modeling system provides a computationally efficient mechanism for preparing specialized inputs for air quality modeling application, and it makes air quality forecasting possible. For example, the National Weather Service uses the CMAQ model to produce daily U.S. forecasts for ozone air quality. The SMOKE system has been used nationwide more than a decade, since it is a reliable, effective, and required emission processor for the powerful CMAQ and CAMx models in air quality modeling studies in the United States.

The SMOKE processes emissions from point sources, such as airports, industrial boilers, petroleum refineries, forest fires, power plants. The emissions from these individual point sources could affect the air pollutant concentrations in a larger area. When the SMOKE processes criteria gaseous pollutants such as carbon monoxide (CO), nitrogen oxides (NOx), volatile organic compounds (VOC), ammonia (NH_3), sulfur dioxide (SO_2); particulate matter (PM) pollutants such as PM 2.5 microns or less (PM-2.5) and PM less than 10 microns (PM-10), these emissions could come not only from point sources, but also from area sources, mobile sources (onroad and nonroad), and biogenic sources. As the last stage of the SMOKE processes, the SMOKE merges individual emissions from all sources into one combined emissions. The MAG air quality modeling staff uses chemically speciated, hourly and gridded anthropogenic and biogenic emissions developed by the SMOKE for the photochemical air quality modeling analysis.

Comprehensive Air Quality Model with Extensions

The Comprehensive Air Quality Model with Extensions (CAMx) is an Eulerian photochemical dispersion model that allows for estimation of gaseous and particulate air pollution (ozone, particulates, air toxics, and mercury) over many scales ranging from neighborhoods to continents. As designed to unify all of the technical features required of state-of-the-science air quality models, CAMx simulates the emission, dispersion, chemical reaction, and removal of pollutants by implementing the Eulerian continuity equation on a system of nested three-dimensional grids. CAMx requires comprehensive input files including gridded emissions supplied by emissions models, initial/boundary conditions provided by global chemical transport models, gridded geographic data developed from land use and land cover data, atmospheric radiative data derived from satellite measurements, and 3-dimensional gridded meteorological fields supplied by prognostic meteorological models.

The MAG air quality modeling staff utilizes this model for the development of attainment and maintenance plans for NAAQS by demonstrating attainment or maintenance of air quality standards, estimating the contributions of multiple source areas, source categories, and pollutant types to local air pollutants concentrations, and evaluating sensitivity of local air pollutant concentrations to air pollutant emissions.

Community Multiscale Air Quality Model

The Community Multiscale Air Quality (CMAQ) modeling system is designed to predict air quality by including state-of-the-art atmospheric sciences for modeling multiple air pollutants. The model simulates tropospheric ozone, fine particles, toxics, acid deposition, and visibility degradation. Initial and boundary condition data developed by a global chemical transport model (GEOS-Chem or CAM-Chem) are used to evaluate impacts of the background air quality, long-range transport, and stratospheric ozone influence on the regional air quality. The MAG air quality modeling staff has used CMAQ and CAMx models for the development of State Implementation Plans and air quality modeling analysis research.

Community Multiscale Air Quality Model with Carbon Bond 6 Chemical Mechanism

The Carbon Bond Chemical Mechanism version 6 (CB6) has been developed by ENVIRON for photochemical air quality modeling analysis in 2010. The new carbon bond chemical mechanism (CB6) had been evaluated through 339 chamber experiments at the University of California at Riverside and the Tennessee Valley Authority. The number of atmospheric chemical reactions in the CB6 increased from 156 to 218 in comparison with the older chemical mechanism version 5 (CB5). The number of chemical species also increased from 51 to 77. The chemistry for gas phase, aromatics, and isoprene is comprehensively updated in CB6.

ENVIRON successfully implemented CAMx with the CB6 for its air quality modeling analysis. However, CB6 has not been implemented or evaluated with CMAQ model. To use the updated CB6 chemical mechanism and improve the MAG photochemical air quality modeling analysis, the MAG air quality modeling staff successfully incorporated the CB6 into the latest CMAQ model. The performance evaluation for the CMAQ/CB6 model showed a significant improvement in predicting ozone concentrations in comparison with the CMAQ/CB5 model.