Proposal for Improved Biogenic Emission Inventories across the West

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1.0 INTRODUCTION

ENVIRON is pleased to respond the Western Governors' Association (WGA) request for proposal (RFP) titled "Improved Biogenic Emission Inventories across the West." We have assembled a well-qualified and experienced team (ENVIRON Team) comprised of staff from ENVIRON's air quality practice in Novato, California, Dr. Alex Guenther and Wildland Solutions.

The proposed co-Principal Investigators, Dr. Greg Yarwood of ENVIRON and Dr. Guenther, have collaborated on numerous projects over the past 15 years to develop biogenic emission models and perform field studies to collect data for biogenic inventories. Mr. Keith Guenther of Wildland Solutions joins the ENVIRON team to assist Dr. Guenther with analyses of geographical data (using GIS) for the improved biogenic emissions. This same team has worked together successfully on the biogenic emissions study for Phoenix, Arizona, that is discussed in the RFP.

ENVIRON is leading the closely related West-wide Jumpstart Air Quality Modeling Study (WestJump AQMS) to develop new photochemical modeling databases for the West. The WestJump AQMS will rely upon the improved biogenic emission inventories developed through this RFP. Mr. Ralph Morris of ENVIRON is leading the WestJump AQMS and would be an advisor to the ENVIRON Team for this study to assist WGA in providing close linkage between both studies.

We believe that the ENVIRON Team's demonstrated experience in developing biogenic emission models and inventories, combined with ENVIRON's understanding of air quality in the West and leading role in the WestJump AQMS, offers WGA the strongest possible team for delivering technically defensible and improved biogenic inventories within the rapid schedule required by this RFP.

1.1 BACKGROUND

The Western Regional Air Partnership (WRAP) is a voluntary partnership of states, tribes, federal land managers, local air agencies and the US EPA whose purpose is to understand current and evolving regional air quality issues in the West. The RFP identifies the following issues as being of interest to WRAP:

- Implementation and future planning for the Regional Haze Rule;
- Air quality issues related to ozone, particulate matter, nitrogen deposition and critical loads, mercury, and other pollutants;
- Emissions sources from all sectors, both domestic and international;
- Effects of air pollution transport; and
- Effects of climate change on regional air quality.

The ENVIRON Team considered WRAP's stated interests in preparing our proposal. For example, the proposed improved biogenic emissions model would have the (optional) capability to account for effects of climate change. ENVIRON also considered the fact that the BEIS3 biogenic emissions model, developed by U.S. EPA, is supported by data that are richer and more detailed for the Eastern U.S. than the Western U.S. The major focus of our proposal is improving data that drive biogenic emission inventories in the West to account for important

factors such as inter-annual variability in vegetation due to drought, land cover change due to progressive urbanization, the biogenic VOC emission potential of Western plants and ecosystems, and the importance of correctly characterizing biogenic NOx emissions in sparsely populated Western regions.

The WestJump AQMS project is developing new photochemical modeling databases for a 2008 base year. The candidate WestJump air quality modeling domains are shown in Figure 1-1 with the "WESTUS" 12-km domain encompassing the Western States of most interest to WRAP. The large 4-km domain can support smaller 4-km domains over areas of interest. Gridded (model-ready) biogenic emissions will be needed for the WestJump air quality modeling domains.

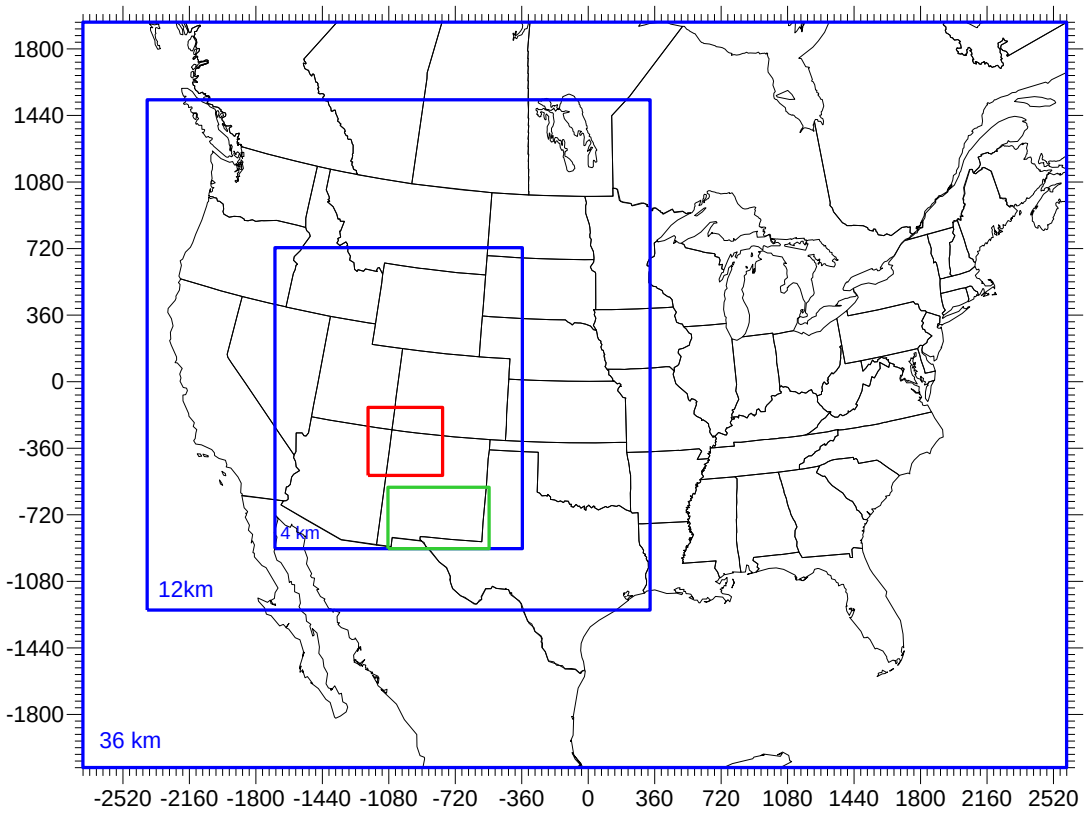


Figure 1-1. Candidate WestJump air quality modeling domains showing the 36-km CONUS and 12-km WESTUS domains. The large 4 km domain can support multiple smaller 4-km domains over areas of interest.

The WestJump project is developing meteorological data (using WRF) for 2008 on domains that encompass those shown in Figure 1. The WestJump meteorological data could be used to develop model-ready biogenic inventories under this study provided that a base year of 2008 is selected by WRAP and the WestJump data are available in time. Potential alternative sources of meteorological data are modeling projects being performed for the states of Wyoming (for 2008) and Utah (for 2010) or the ROMANS study (for 2009) although these studies are using different modeling domains.

1.2 SUMMARY OF PROPOSED APPROACH

The ENVIRON Team's approach to completing the four Tasks in the RFP is summarized as follows:

Task 1. Analysis Technical Report

The biogenic emissions model used for this task will be MEGAN version 2.10 which will have several improvements over the existing MEGAN version 2.04 including 1) a soil NOx emission algorithm that accounts for fertilizer application and precipitation, 2) the ability to use a more frequent 8-day average Leaf Area Index (LAI) rather than monthly average LAI, 3) an explicit canopy model that calculates leaf temperature and light of sun and shade leaves for five canopy depths, 4) improved algorithms and emission factors for biogenic VOC including (optionally) response to increasing carbon dioxide levels and long-term changes in climate. We propose to provide western U.S. land-use and landcover data that represents a substantial improvement over what has previously been available to biogenic emission modelers including 1) plant functional type fractional (PFTf) coverage data based on 30 meter Landsat TM data, 2) emission factors based on recent emission measurements in the Western U.S. and elsewhere and on improved U.S. species composition data, and 3) LAI based on revised satellite measurements that are for a specific year and with higher (8-day) temporal resolution.

Task 2. Western Regional 2008 Biogenic Emissions Inventory

This task will prepare improved Western U.S. regional biogenic emissions for 2008 using the improved model and input data from Task 1, and assess the results. The new emission inventories will be compared against MEGAN v2.04 with standard configurations and input data and SMOKE-BEIS 3.14 with standard configurations and input data to understand the differences and for quality assurance.

Task 3. 2008 Photochemical Grid Model-ready Datasets

This task will prepare photochemical grid model-ready biogenic emissions for 36/12/4-km modeling domains for the WestJump AQMS for year 2008. The biogenic emissions model used for this task will be the improved model and input data from Tasks 1 and 2. The model-ready biogenic emissions will be delivered on external hard-drives that are suitable for distribution by WRAP.

Task 4. Final Report

This task will develop a draft and final project report and deliver it to the WGA project committee electronically in MS Word and PDF formats. The final report will incorporate task

reports from Tasks 1 to 3 to provide a comprehensive overview of the technical activities undertaken during the project.

1.3 RESPONSIVENESS TO RFP EVALUATION CRITERIA

The ENVIRON Team has prepared a proposal that is responsive to all of the evaluation criteria listed in the RFP. Below, we highlight how our proposal responds to each criterion:

1. The ability to provide sound technical support: We believe that the ENVIRON Team offers WGA the strongest possible team for delivering technically defensible and improved biogenic inventories within the rapid schedule required by this RFP. We hope that our proposed technical approach (Section 2) and qualifications (Section 3) will sustain this view.
2. Experience with similar projects: Our experience with similar projects is described through our project and personal qualifications in Section 3 and Appendix A.
3. Personnel qualifications: Our personal qualifications are presented as biographical sketches in Section 3 and resumes in Appendix A.
4. Availability and support of management: Dr. Greg Yarwood of ENVIRON is one of the proposed co-Principal Investigators who will be directly available to the WGA and, as an ENVIRON principal; can ensure management commitment to the project.
5. Completeness and clarity of the proposal: Our proposal is intended to address completely the requirements of the RFP and we will be happy to provide clarifications or supporting information upon request.
6. Cost: We present cost information, broken down by task, in a separate document.
7. Schedule: Our proposed schedule is shown in Section 3 and meets the requirements of the RFP.
8. Offers of in-kind (no cost to the WGA) services from the bidder's organization, which will be reviewed under established WGA procedures: We do not propose any formal cost sharing. However, we note that our proposal gains efficiency by leveraging existing work to improve the MEGAN model and close coordination with the WestJump AQMS project.

2.0 Technical Approach

In this section of the proposal we present the ENVIRON Team's proposed technical approach to completing the four Tasks identified in the RFP.

2.1: ANALYSIS TECHNICAL REPORT

Task 1 Objectives

The objective of this task is to prepare an Analysis Technical Report on an improved biogenic emissions model and input variables. The biogenic emissions model used for this task will be MEGAN version 2.10 which will have several improvements over the existing MEGAN version 2.04 including 1) a soil NOx emission algorithm that accounts for fertilizer application and precipitation, 2) the ability to use a more frequent 8-day average Leaf Area Index (LAI) rather than monthly average LAI, 3) an explicit canopy model that calculates leaf temperature and light of sun and shade leaves for five canopy depths, 4) improved algorithms and emission factors for biogenic VOC including (optionally) response to increasing carbon dioxide levels and long-term changes in climate. We propose to provide western U.S. land-use and landcover data that represents a substantial improvement over what has previously been available to biogenic emission modelers including 1) plant functional type fractional (PFTf) coverage data based on 30 meter Landsat TM data, 2) emission factors based on recent emission measurements in the Western U.S. and elsewhere and on improved U.S. species composition data, and 3) LAI based on revised satellite measurements that are for a specific year and with higher (8-day) temporal resolution.

Key Personnel

Dr. Alex Guenther would be Task Leader for the Analysis Technical Report to take advantage of his experience as lead developer of the MEGAN model. Dr. Guenther would coordinate closely with Dr. Tan Sakulyanontvittaya of ENVIRON who would lead Task 2 and 3 to implement and apply the improved modeling approach developed in Task 1. Dr. Greg Yarwood would provide advice on coordinating improvements to the biogenic emissions model with requirements of air quality models. Mr. Ralph Morris would provide a link to the WestJump AQMS project. Mr. Keith Guenther of Wildland Solutions will perform analyses of geographic data for the improved biogenic inventory.

Technical Approach

Biogenic emissions from terrestrial ecosystems are a major source of VOCs and a significant contributor to NOx and CO emissions in the western U.S. Accurate representations of these emissions are required for efforts to understand and improve regional air quality including regional haze, ozone, and nitrogen deposition. Biogenic emissions are estimated with numerical models that simulate the response of biogenic emissions to variations in weather, landcover and (optionally) climate.

The current official release of the MEGAN model is version 2.04 and it is available from http://acd.ucar.edu/~guenther/MEGAN/MEGAN.htm. A new version, MEGAN 2.1, is scheduled to be released to the scientific and regulatory communities on September 1, 2011. MEGAN 2.1 will include an explicit canopy model that calculates leaf temperature and light of sun and

shade leaves for five canopy depths and improved algorithms and emission factors for biogenic VOC including (optionally) response to increasing carbon dioxide levels and long-term changes in climate. For this project, we propose to include two additional enhancements for MEGAN 2.1: 1) a soil NOx emission algorithm that accounts for fertilizer application and precipitation, 2) the ability to use 8-day average LAI rather than monthly average LAI. These enhancements to the MEGAN 2.1 code will be conducted as a component of Task 2 and the modified MEGAN 2.1 code will be available for the modeling activities proposed for Task 3.

MEGAN v2.04 has a very simple soil NOx emission model that considers only landcover type and temperature to estimate emissions. BEIS3.14 has adopted a more sophisticated soil NOx algorithm, based on Yienger and Levy (1995), that includes the impact of fertilizer application rates and precipitation, both of which have been shown to be important drivers of soil NOx emission. We will implement the BEIS 3.14 approach in MEGAN 2.1 by including fertilizer rates, soil moisture, soil temperature, and rain data as drivers of soil NOx emission. The MEGAN meteorological pre-processor will be modified to include these variables.

Leaf Area Index (LAI)

MEGAN is typically driven with the default 30 second (~1km) LAI data provided on the MEGAN data portal (see cdp.ucar.edu/acd/megan/). This data is for the year 2003 and is based on an early version of the MODIS satellite LAI data product. For this project, we would develop a substantially improved 1 km LAI input database for driving MEGAN biogenic emissions in the western U.S. for a specific year. This could be for the year 2008 or for any other year from 2002 to 2010. The improvements include 1) using more accurate LAI data, 2) using data that are representative of the year 2008, and 3) using 8-day average LAI data rather than monthly average LAI data.

The accuracy of the LAI data should be considerably improved by using the latest version of the MODIS satellite data product. In the past several years, considerable effort has gone into improving the algorithms used to relate the reflectances measured by the MODIS satellite to LAI (Garrigues et al. 2008). Thus we expect the revised MODIS LAI data product to be more accurate than the earlier data that is currently provided on the MEGAN data portal. Our preliminary analysis indicates that the differences between the new and older product for the year 2003 are considerable in some regions which is in agreement with an assessment by the California Air Resources Board which found that using the new LAI product can make a significant difference in estimated biogenic VOC emission rates (Jeremy Avise, personal communication, 2010).

LAI distributions can vary considerably on an inter-annual basis and LAI can influence biogenic VOC emission estimates, as showed in Figure 2-1. Warneke et al. (2010) compared isoprene concentrations observed with an airborne sampling system with air quality model estimates based on MEGAN and BEIS3 isoprene emissions. They found that LAI over the eastern Texas study region varied considerably from year to year with a significant impact on isoprene emissions. The use of year specific LAI data is likely to be most important in relatively arid regions such as the western U.S. We will develop MEGAN LAI inputs using 2008 MODIS data and will compare these data, for selected Western U.S. regions, with the following alternative LAI data:

- year 2003 LAI that is currently available in the MEGAN data portal
- year 2003 LAI data based on new MODIS data product
- year 2009 LAI data based on new MODIS data product
- year 2010 LAI data based on new MODIS data product

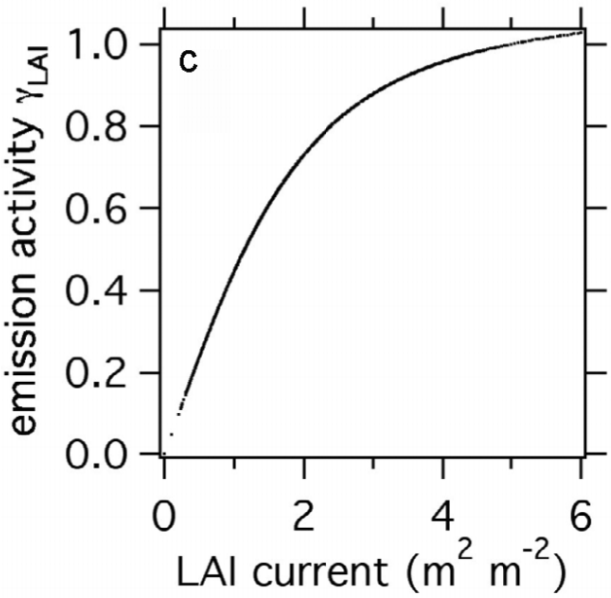


Figure 2-1. LAI emission activity factors used to scale VOC emission in MEGAN modeling against LAI data from the TexAQS2006 campaign (Warneke et al., 2010).

MEGAN uses time dependent LAI to account for seasonal changes in the amount of foliage and to estimate foliar age which is important because new, young, mature and senescing foliage has very different biogenic VOC emission rates (Guenther et al. 2006). MEGAN is typically run using monthly average LAI. For this project, we propose to use 8-day average LAI which will require a modification to the MEGAN code and will require the processing of 46, rather than 12, LAI files for the year 2008 or for another requested year. We will assess the spatial and temporal impact of utilizing 8-day average LAI by comparing model estimates using 8-day and monthly LAI data for selected Western U.S. regions.

Plant Functional Type fraction (PFTf)

MEGAN is typically driven with the 30 second (~1 km) PFTf data archived in the MEGAN data portal (cdp.ucar.edu/acd/megan/). This global data set includes the fraction of each 30 second x 30 second cell covered by each of 4 PFTs: Broadleaf trees, Needleef trees, shrubs, and herbaceous. The default MEGAN PFTf data is based on AVHRR and MODIS data from year 2001 (Guenther et al. 2006). Figure 2-2 shows that this database can reasonably represent PFTs in homogeneous regions but may perform poorly in heterogeneous regions including urban areas, mixed cropland and forest, and open woodlands (Duhl et al. 2011). For this project, we propose to improve MEGAN PFTf inputs for the U.S. by using landcover data based on high resolution

(30 m) imagery. We propose to use the 2006 NLCD tree cover, impervious cover and landcover data (see www.mrlc.gov) to derive a 30 m resolution PFTf database for MEGAN. Since the NLCD tree cover product tends to underestimate tree cover in urban areas, we will account for this using correction factors determined for various urban regions throughout the Western U.S. We will aggregate the 30 meter data to 30 second resolution (~ 1 km) and compare the new and old MEGAN PFTf distributions for the western U.S. and consider the implications for biogenic VOC, CO, and NO_x emission estimates.

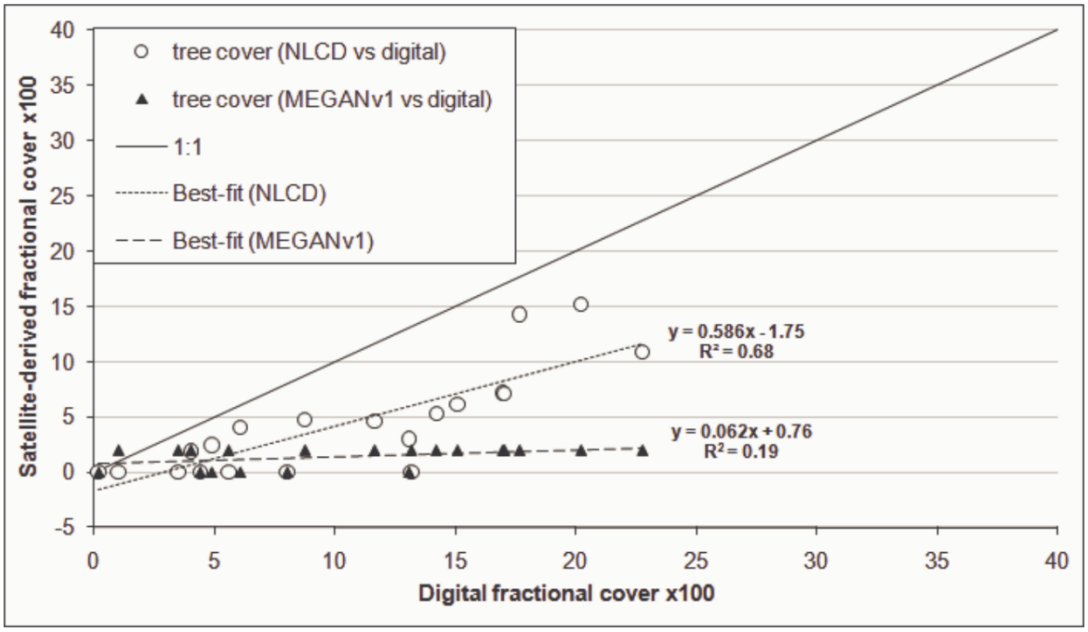


Figure 2-2 Comparison of tree cover fraction estimates for Maricopa County, AZ using MODIS based MEGANv1, LANDSAT TM based NLCD, and digital high resolution imagery (Duhl et al. 2011).

Emission Factors

One of the challenges associated with biogenic emission modeling is the large variability in biogenic VOC emission rates, especially for compounds such as isoprene, methyl butenol and a-pinene. Isoprene emission rates range over 5 orders of magnitude for various plants species. MEGAN accounts for this using a geo-gridded map of isoprene emission factors for each of the 4 PFTs that accounts for spatial variations in plant species composition. Each geo-gridded map combines species composition data for a particular location with species-specific emission factors to generate emission factors for each location. These PFT average emission factors are then combined with the estimates of PFTf for each location to estimate the grid average emission factor for each compound. Geo-gridded maps are estimated for the ten compounds that dominate the total biogenic VOC. For the remaining ~140 compounds, each of which makes only a very small contribution to the total emission, constant emission factors are assigned to each of the 4 PFTs and the PFT-weighted average is used to calculate the emission factor at each location.

The MEGAN emission factors available for download from the MEGAN data portal (see cdp.ucar.edu/acd/megan/) are based on species composition data from the USFS FIA for trees (see fia.fs.fed.us), NRCS for shrubs and grass (see soildatamart.nrcs.usda.gov) and NASS for crops (www.nass.usda.gov). The crop data were averaged over U.S. counties and the tree, shrub and grass data were averaged over USGS GAP landcover categories which were available for the U.S. on a 1 km grid. For this project, we propose to develop an improved species composition database using an approach that integrates high resolution (56 m) land-use and landcover data (cropland data layer (CDL), see nassgeodata.gmu.edu) that is available for specific years (e.g., 2008, 2009, 2010) with NASS crop, FIA tree and NRCS shrub and grass species information. The CDL landcover data will be used to determine the land-use (urban, agriculture, or wildland) of each 56m grid cell. Urban areas will be assigned species composition based on a compilation of urban vegetation inventories. Agriculture will be assigned the plant species indicated by the CDL crop type (over 200 crop types are given including double crops). Wildland will be assigned the plant species determined for the over 1000 U.S. ecoregions. The resulting product will have a more accurate species distribution than the existing MEGAN data and will also enable characterization of inter-annual variations in species distributions associated with urbanization, cropland expansion and crop rotation. We will develop an emission factor database for a specific year for which the data are available (2008, 2009 or 2010). We will assess the impact of year-to-year changes in species composition using landcover data for 2008, 2009, and 2010 for selected Western U.S. regions.

The species composition data will be combined with the MEGAN species-specific emission factor database to generate area averaged emission factors. A literature review will be conducted to include recent biogenic VOC emission measurements, especially in the Western U.S., in the MEGAN species-specific emission factor database. This includes recent measurements (e.g., Papiez et al. 2009, Jardine et al. 2010, Kim et al. 2010, Guenther et al. in preparation) conducted by Dr. Guenther and colleagues in Colorado, California, New Mexico, Arizona, Wyoming, and Nevada.

Task 1 Deliverables

The main Task 1 deliverables will be a draft Analysis Technical Report, a final Analysis Technical Report and electronic copies of geo-gridded databases at 30 second (~1 km) spatial resolution that can be used for developing MEGAN input files for Western U.S. for the year 2008 (or for 2009 or 2010 if requested) including emission factors for 15 chemical species, 4 PFTs and 46 LAI 8-day averages.

2.2: WESTERN REGIONAL 2008 BIOGENIC EMISSIONS INVENTORY

Task 2 Objectives

The objective of this task is to prepare improved Western U.S. regional biogenic emissions for 2008 and assess the results. The biogenic emissions model used for this task will be MEGAN version 2.10 (as developed in Task 1) with several improvements over the existing MEGAN version 2.04. The input data for MEGAN will include a high-quality performance-tested 2008 meteorological dataset and the improved landcover (LAI and PFTf) and emission factor data developed for Task 1. The emission inventory will be delivered to WRAP in a database of county-level VOC, NOx and CO emissions totals for an average July day. The new emission

inventories will be compared against MEGAN v2.04 with standard configurations and input data and SMOKE-BEIS 3.14 with standard configurations and input data to understand the differences and for quality assurance.

Key Personnel

Dr. Tan Sakulyanontvittaya would be Task Leader for the Western Regional 2008 Biogenic Emissions Inventory to take advantage of his experience as lead developer of the MEGAN model. Dr. Sakulyanontvittaya would coordinate closely with Dr. Alex Guenther who would lead Task 1, to ensure the correct implementation of the new model code and input variables.

Technical Approach

Terrestrial ecosystems are a source of VOC, CO and NO emissions into the atmosphere. Thus accurate predictions of biogenic VOC, CO and NO emissions are important for developing regulatory ozone and aerosol control strategies for at least some rural and urban areas. A biogenic emission inventory will be developed for the Western U.S. and the results and performance will be carefully assessed.

MEGAN version 2.1, with the improvements implemented for Task 1, will be used to estimate speciated volatile organic compounds, carbon monoxide, and nitrogen oxides for the 4-km, 12-km and 36-km WestJump air quality modeling domains (Figure 1). In addition to using an updated version of MEGAN, the emission model calculations will be based on the improved landcover and emission factors developed for Task 2.1. The 30 sec (~1-km) resolution landcover and emission factor databases for 2008 developed for task 2.1 (46 for LAI, 4 for PFT and 15 for emission factors) will be averaged over the 4-km, 12-km and 36 km WRAP domains.

Besides the model inputs described above, biogenic emission estimates require meteorological data. For this project, we will use 2008 WRF gridded meteorological data for the West from the WestJump AQMS project or seek alternative meteorological data to be used under this task and Task 3. Potential alternative sources of meteorological data are modeling projects being performed for the states of Wyoming (for 2008) and Utah (for 2010) or the ROMANS study (for 2009).

The new emission inventories developed under this task will be compared against MEGAN v2.04 and SMOKE-BEIS 3.14 to understand the differences and for quality assurance. A hot summer month, expected to have high biogenic emissions, e.g. July, will be selected for the emission estimates using; 1) the improved MEGAN v2.10 with the new input data, 2) standard MEGAN v2.04 with standard configurations and input data, and 3) standard SMOKE-BEIS with standard configurations and input data. Different comparisons, e.g. monthly average diurnal variation, monthly total spatial variation, and monthly total emission tables by domains, county, and landuse type, will be performed and used to understand the differences among the models and for quality assurance. The emission inventory will be delivered to WRAP in a database of county-level VOC, NOx and CO emissions totals for an average July day.

The draft biogenic emission inventory and the assessment will be thoroughly examined and reviewed and the results presented to the WRAP Biogenics Project Steering Committee, and other interested technical staff of state and federal agencies, for input and comments so that

any issues can be addressed prior to preparing the Photochemical model ready data in Task 3. The assessment of the model results will include an analysis of the factors driving temporal and spatial variations and a comparison with other model estimates.

Inventory Development

MEGAN version 2.10 will have several improvements over the existing MEGAN version 2.04. The major improvements are; 1) a soil NOx emission algorithm that accounts for fertilizer application and precipitation, 2) the ability to use a more frequent 8-day average Leaf Area Index (LAI) rather than monthly average LAI, 3) an explicit canopy model that calculates leaf temperature and light of sun and shade leaves for five canopy depths, 4) improved algorithms and emission factors for biogenic VOC including response to increasing carbon dioxide levels and long-term changes in climate. The implementations of these improvements require modifications to the MEGAN input format and preprocessor in addition to the modifications to the model. In addition to solar radiation and temperature, other meteorological data, soil moisture, soil temperature, and rain data are necessary for the soil NO_x emission algorithm. These meteorological data could be retrieved from many formats, such as MM5, WRF, CMAQ-MCIP, and CAMx meteorological data. ENVIRON has developed and used a meteorological pre-processor, temperature and PAR pre-processor, to reformat various meteorological data formats for MEGAN. It would maximize cost-benefit to upgrade the temperature and PAR pre-processor to prepare meteorological data for soil NOx algorithm and integrate the preprocessor into the MEGAN model. In addition, it will benefit the future development of biogenic emission modeling. For this task, we will develop a meteorological preprocessor which has ability to retrieve necessary meteorological data from various formats and we will integrate the preprocessor into MEGAN v2.10.

Task 2 Deliverables

The main Task 2 deliverables will be the emission inventory in a database of county-level VOC, NOx and CO emissions totals for an average July day and a biogenic emission inventory report describing the inventory and comparisons to other models. In addition, model ready emissions for July will be delivered in CB05 format for the following cases:

- MEGAN v2.04 for CAMx
- MEGAN v2.04 for CMAQ
- BEIS3.14 for CAMx
- BEIS3.14 for CMAQ
- MEGAN v2.10 for CAMx
- MEGAN v2.10 for CMAQ

2.3: 2008 PHOTOCHEMICAL GRID MODEL-READY DATASETS

Task 3 Objectives

The objective of this task is to prepare photochemical grid model-ready biogenic emissions for the WestJump AQMS 36/12/4-km air quality modeling domains for year 2008 and, optionally, a second year to be selected later. The biogenic emissions model used for this task will be the improved MEGAN version 2.10 developed for Tasks 1 and 2 with revised NOx algorithm, ability

to use 8-day average LAI, and an explicit canopy model. The improved emission inventories and new landuse from Tasks 1 and 2 will be used in the improved MEGAN version 2.10 to create the photochemical grid model-ready biogenic emissions.

Key Personnel

Dr. Tan Sakulyanontvittaya of ENVIRON would be Task Leader for development of photochemical grid model-ready datasets to take advantage of his experience in developing and running the MEGAN model. Dr. Sakulyanontvittaya would coordinate closely with Dr. Guenther to ensure that the model-ready emissions are consistent with expectations from Tasks 1 and 2.

Technical Approach

Biogenic emissions are a key input to photochemical models because they are often the dominant source of VOCs at regional scales. Consequently, biogenic emissions can control how ozone formation responds to anthropogenic NOx and VOC emissions. In addition, many biogenic VOCs also are precursors for secondary organic aerosol (SOA) and so the biogenic emissions directly influence PM formation.

MEGAN is one of the main biogenic emission models used in the U.S. and worldwide. It uses hourly meteorological data, Emission Factors (EF) by pollutant, monthly average Leaf Area Index (LAI), Plant Functional Type fraction (PFTf) for estimating biogenic emissions. Like any model, accuracy of emission estimates in MEGAN is limited by the accuracy of model input data. Therefore, accurate model inputs are important. As explained in Section 2.1, we will develop 2008 WGA 36/12/4 km biogenic emission inventories by using the improved and up-to-date EF, LAI, and PFTf data as approved by WGA committees. Optionally, model ready emissions also would be developed for a second year. The improved MEGAN v2.10, rather than the current release MEGAN v.2.04, will be used in this task. The major improvement in MEGAN v2.10 over MEGAN v2.04 are; a soil NOx emission algorithm that accounts for fertilizer application and precipitation, 2) the ability to use a more frequent 8-day average Leaf Area Index (LAI) rather than monthly average LAI, 3) an explicit canopy model that calculates leaf temperature and light of sun and shade leaves for five canopy depths, 4) improved algorithms and emission factors for biogenic VOC including response to increasing carbon dioxide levels and long-term changes in climate. The model ready emissions will be formatted for the Carbon Bond mechanism, either CB05 or CB6. Optionally, model ready emissions can be delivered in the format for the SAPRC07 chemical mechanism in addition to the Carbon Bond mechanism. Model ready emission files will be delivered in both CAMx and CMAQ (netCDF) format.

Biogenic emission estimates require meteorological data. For this project, we will use 2008 WRF gridded meteorological data for the West provided by WGA or alternative meteorological data, depending on availability and with approval from the WRAP Biogenics Project Steering Committee. Potential alternative sources of meteorological data are modeling projects being performed for the states of Wyoming (for 2008) and Utah (for 2010) or the ROMANS study (for 2009).

Task 3 Deliverables

The main Task 3 deliverables will be a Task 3 Report and electronic copies of the improved MEGAN model version 2.10 and the biogenic emission inventories for the 36/12/4 km modeling grids for year 2008. The model-ready biogenic emissions will be delivered on external hard-drives that are suitable for distribution by WRAP. Model ready emission files will be delivered in both CAMx and CMAQ (netCDF) format for the Carbon Bond mechanism (CB05 or CB6).

Optionally, model ready emissions for a second year can be delivered by exercising Options 1a or 1b. Option 1a would deliver emissions for a second year by changing the meteorological data but keep all other inputs to MEGAN the same as for 2008. Option 1b would deliver emissions for a second year by changing both the meteorology and vegetation data (LAI and PFT).

Optionally, model ready emissions can be delivered in the format for the SAPRC07 chemical mechanism in addition to the Carbon Bond mechanism by exercising Option 2.

Optionally, the gridded vegetation input data for the MEGAN model can be delivered in the format of ARCGIS shape files by exercising Option 3.

2.4: FINAL REPORT

Task 4 Objectives

The objective of this task is to develop a draft and final project report and deliver it to the WGA project committees electronically in MS Word and PDF formats. The final report will incorporate task reports from Tasks 1 to 3 to provide a comprehensive overview of the technical activities undertaken during the project.

Key Personnel

Dr. Tan Sakulyanontvittaya of ENVIRON would be Task Leader for the project report to take advantage of his experience in developing and running the MEGAN model and other biogenic emission models. Dr. Sakulyanontvittaya would coordinate closely with Dr. Guenther, who would lead Task 1, to ensure the correct procedure of input preparation and implementation of the new model code in the report. The final report will show emission density plots for both summer and winter days.

Technical Approach

The final report will include:

1. An executive summary;
2. A brief introduction describing the background and objectives for this project;
3. A summary of the development of MEGAN EF, PFTf, and LAI data, including procedures, assessment results;
4. A summary of the development of the MEGAN version 2.10 model and meteorological preprocessor;
5. A discussion of accomplishments, shortfalls, and limitations of the work completed in this project; and

6. Recommendations for further study, if any.

3.0 MANAGEMENT, EXPERIENCE AND QUALIFICATIONS

3.1 MANAGEMENT PLAN

The ENVIRON Team has developed a project management plan that will provide clear lines of communication to the project sponsors (the WGA and WRAP Biogenics Project Steering Committee) and within the ENVIRON Team. The proposed project organization is shown in Figure 3-1. Dr. Greg Yarwood of ENVIRON and Dr. Alex Guenther are the proposed co-Principal Investigators responsible for study technical direction and for communication with the project sponsors. Mr. Ralph Morris of ENVIRON would advise the co-PIs by providing information on technical activities being conducted by the West-wide Jumpstart Air Quality Modeling Study (WestJumpAQMS) project for which he is the Principal Investigator.

A Task Leader is assigned to each of the four tasks specified in the RFP. The Task Leaders will direct all of the day-to-day aspects of the study using Dr. Yarwood as a technical resource for the overall study direction and interpretation. Dr. Alex Guenther would lead Tasks 1 and 2 to review available biogenic emission models/data and develop an improved biogenic emissions model for the West. Dr. Tan Sakulyanontvittaya will have an important role implementing improvements to the MEGAN model under Task 2. Dr. Sakulyanontvittaya would lead Task 3 to produce the model-ready emission inventories using the improved biogenic emissions model for the West. Dr. Yarwood would lead the preparation of the final project report in Task 4 relying upon contributions from Drs. Guenther and Sakulyanontvittaya. Mr. Keith Guenther of Wildland Solutions will assist Dr. Alex Guenther with GIS processing of new data for the improved biogenic emission inventory.

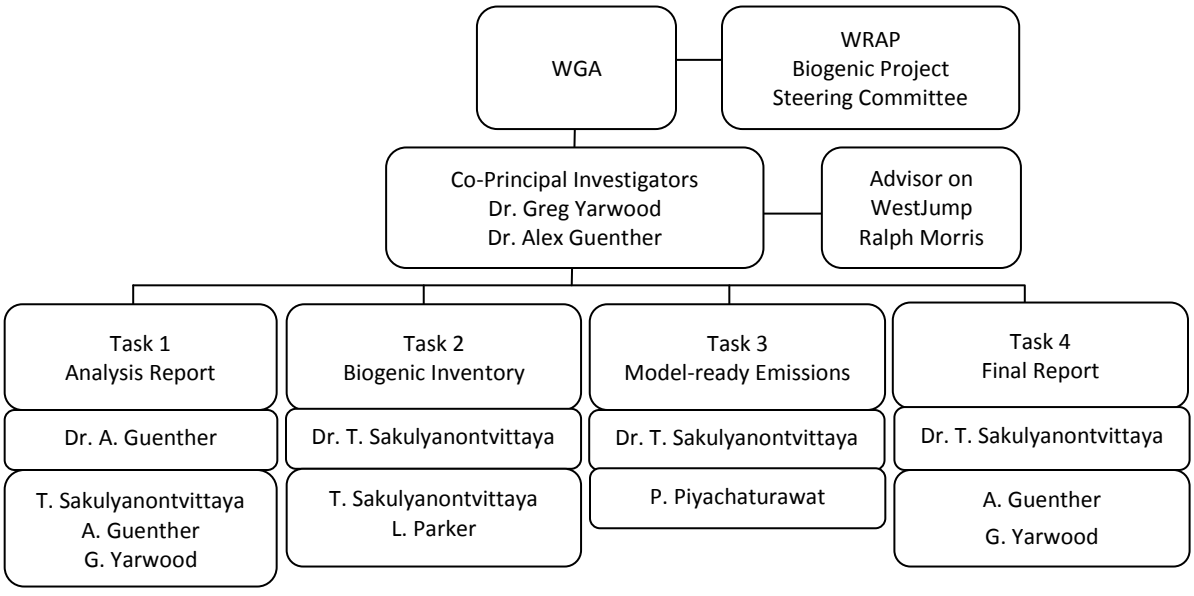
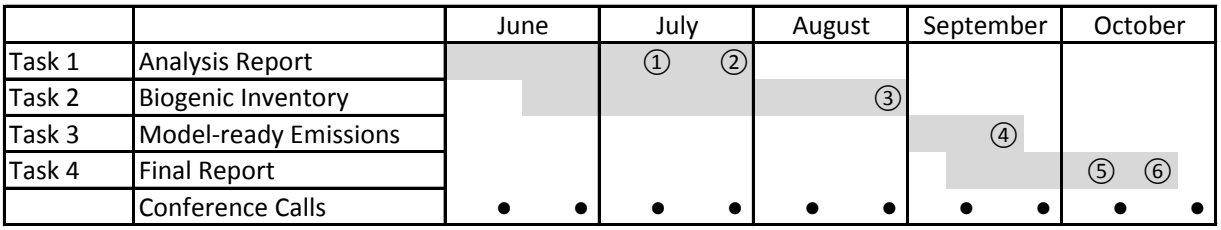


Figure 3-1. Management structure for the ENVIRON Team showing the relationship to the project sponsors and the technical leader for each Task.

The ENVIRON Team's proposed timeline for completing the project is shown in Figure 3-2.



Deliverable

① Draft analysis technical report (July 10, 2011)
② Final analysis technical report (July 29, 2011)
③ Biogenic emissions inventory (August 29, 2011)
④ Photochemical grid model-ready emissions (September 26, 2011)
⑤ Draft final report (October 10, 2011)
⑥ Final report (October 24, 2011)

Figure 3-2. Proposed project timeline and deliverable dates.

Task deliverables and due dates are specified. In Figure 3-1, monthly deliverables during the duration of this project will include a written project status report for the WRAP Biogenic Project Steering Committee, describing progress on project deliverables, obstacles encountered, and planned activities. The report will be delivered at the end of the months during the duration of this project. The reports, inventory, and model-ready emissions deliverables are subject to review and approval by the State air agencies, to be coordinated by WGA and WESTAR Council staff as noted in the RFP. Each project status report will contain any necessary narrative about the progress of review and approval activities by State air agencies to complete these project deliverables, as well as any impacts on the project schedule. The RFP calls for biweekly conference calls which we propose to conduct on the second and final Thursday of each month. Discussion of any topics related to the review and approval of deliverables can be included in these calls. The following schedule for conference calls is proposed:

June 9
June 30
July 14
July 28
August 11
August 25
September 8
September 22
October 13
October 29

3.2 EXPERIENCE AND QUALIFICATIONS

The ENVIRON Team with Dr. Alex Guenther is exceptionally well-qualified to carry out the proposed study to improve biogenic emission inventories across the West. Dr. Guenther is the foremost expert on biogenic emissions modeling in the US and is recognized worldwide for this expertise. He has collaborated with Dr. Yarwood previously to perform several biogenic field studies (in Phoenix, Dallas and Houston) and develop the GloBEIS biogenic emissions model. GloBEIS was developed for the TCEQ to implement BEIS3 emission algorithms in a database framework that facilitates input of local land cover and emission factor data (because the BEIS framework lacked sufficient flexibility). Dr. Sakulyanontvittaya worked with Dr. Guenther on the development of MEGAN by implementing the chemical speciation algorithms needed to prepare model-ready emissions for photochemical modeling. Dr. Sakulyanontvittaya recently developed improved MEGAN input data for Alberta by incorporating locally specific data on plant distributions and biomass.

The ENVIRON Team understands not only biogenic emission models, but also how the products of the proposed study are intended to be used in State Implementation Plan (SIP) modeling. ENVIRON has performed the emissions and air quality modeling for numerous SIPs throughout the US. Consequently, we understand how to integrate the biogenic emissions model into the air quality modeling system most efficiently and making the best use of available input data (e.g., meteorological model output). We also understand how to report the biogenic emission results in a manner that is suitable for inclusion in SIP documentation.

Presented below are: (1) Company Qualifications for ENVIRON; (2) Personal Qualifications for key proposed staff; and (3) Demonstrated project experience and qualifications for studies relevant to the proposed biogenic emission inventory study.

3.2.1 Company Qualifications

ENVIRON International Corporation is a 1,000-person health and environmental consulting firm with offices throughout the United States and several offices in Europe, Asia and Australia. Founded in 1982, ENVIRON has gained a national reputation as a leader in the areas of environmental strategic analysis, regulatory compliance assurance, environmental and public health risk assessment, and risk management. Our multi disciplinary staff is comprised of experts in air, water, and soils science and engineering, and includes environmental and chemical engineers, air scientists, hydrogeologists, toxicologists, chemists, industrial hygienists, other environmental and public health scientists, and regulatory and policy experts.

The Air Sciences Group of ENVIRON is composed of approximately 150 persons, each highly skilled in various aspects of air quality management and science. Team members possess backgrounds in engineering, physics, chemistry, meteorology, mathematics, life sciences, risk assessment, and computer science. ENVIRON Air Sciences staff have skills in emission inventory development for all source categories, dispersion and photochemical modeling, meteorological modeling, control technology assessments, broad based air quality control strategy analyses, emissions standards assessment, environmental data analysis, and environmental data base development.

ENVIRON is well known for its extensive experience in the development and application of photochemical, particulate matter (PM), and visibility air quality models for assessment of ozone, PM and other air quality and air quality related value (AQRV) issues (e.g., mercury, toxics, acid deposition and visibility). The Air Science Group has substantial computing capabilities, allowing for the efficient use of the most sophisticated air quality, emissions, and meteorological models. ENVIRON has developed and publicly released CAMx (the Comprehensive Air quality Model with extensions) for integrated ozone and PM modeling using a "1-atmosphere" approach comparable to EPA's Models-3/CMAQ.. CAMx is currently being used in numerous air quality planning studies throughout the U.S. and around the world. ENVIRON is experienced in the application of other Eulerian grid models (such as CMAQ and GEOS-Chem), Lagrangian puff models (such as CALPUFF/CALMET and SCIPUFF/SCICHEM) and Gaussian industrial source models (such as AERMOD and ISC), advanced meteorological models (such as WRF, MM5 and RAMS) and emissions models (e.g., SMOKE, EPS3, CONCEPT, BEIS3, MEGAN and GloBEIS). Staff of ENVIRON's Air Science Group have performed many large-scale emissions and air quality management studies for many states in the U.S.

3.2.2 Personal Qualifications

Below we provide a brief summary of the personal qualifications for the key personnel from the ENVIRON Team. Complete resumes are provided in Appendix A.

Greg Yarwood, a Principal at ENVIRON, is an international expert with over 20 years experience in atmospheric chemistry, air quality modeling, photochemical model development, interpreting ambient air quality data, and emissions inventory development especially for motor vehicles and biogenic sources. He managed development of the GloBEIS biogenic emissions model (www.globeis.com) and field studies in Texas and Arizona to gather data for biogenic emission inventories. He is an experienced project manager and provides technical direction for projects at ENVIRON. Greg directs air quality, meteorological, and emissions modeling studies for clients in government and industry, with emphasis on photochemical air pollution issues such as ozone, secondary particulate matter (PM), visibility, and air toxics. Greg leads development of ENVIRON's Comprehensive Air quality Model with extensions (CAMx: http://www.camx.com). For USEPA he developed the Carbon Bond 2005 (CB05) chemical mechanism that is used for ozone and PM in CAMx and EPA's CMAQ model. He performed international air quality studies for China and Africa sponsored by agencies such as the World Bank. Greg holds a PhD in chemistry from Cambridge University. He is a member of USEPA's Board of Scientific Counselors for the Clean Air Research Program.

Dr. Alex Guenther is a senior scientist and section head of the Atmospheric Chemistry Division of the National Center for Atmospheric Research, Boulder CO, USA. He manages a section of 16 scientists and engineers with a research budget exceeding US$ 3M. He has investigated biogenic VOC emissions and their role in the earth system for more than 25 years. He is the lead developer of the global Model of Emissions of Gases and Aerosols from Nature (MEGAN) which is widely used by the scientific and regulatory communities. He has led more than 40 field investigations of biosphere-atmosphere interactions on 6 continents in tropical, temperate and boreal ecosystems to provide the observations required to develop and evaluate MEGAN and associated earth system models. Dr. Guenther has published over 200 peer reviewed journal articles. His papers are widely cited, with an H index of 45 and including a Top Ten Most Highly

Cited in Geosciences paper and a recent Fast Moving Front paper. He is currently the co-chair of International Geosphere Biosphere Programme (IGBP) iLEAPS and is a past chair of the IGBP-GEIA activity.

Dr. Tanarit (Tan) Sakulyanontvittaya is an Associate at ENVIRON with more than ten years of US and international experience in air quality modeling and analysis, emission inventory modeling, mobile source emission control technologies and measurement techniques, alternative fuels, and emission factor model development and assessments. Tan is experienced with the CMAQ, CAMx, AERMOD and ISC air quality models, the SMOKE emissions modeling system, the MEGAN, BEIS, and GloBEIS biogenic emissions models. Since joining ENVIRON in 2008, Dr. Sakulyanontvittaya has worked on various biogenic emissions inventory developments, such as developments of Alberta - Canada specific plant distribution for biogenic emission estimates using GIS and MEGAN model, developments and evaluations of biogenic emission models in Texas areas for Texas Commission on Environmental Quality, developments of gridded biogenic emissions for; U.S. Regional Planning Organizations, Phoenix-Arizona area for Arizona Department of Environmental Quality, Treasure Valley area for Idaho Department of Environmental Quality, and other Hong Kong, Europe, and Italy regions. Prior to joining ENVIRON, he studied the impact of biogenic VOC emissions on US air quality and developed the chemical speciation algorithms for the Model of Emissions of Gases and Aerosols from Nature (MEGAN) at the University of Colorado, in collaboration with the National Center for Atmospheric Research (NCAR). Tan is proficient in various programming languages, including FORTRAN, C++, Perl, Python, VB-VBA, and, Linux shell scripting. He is skilled in using modeling and visualizing software, including IDL, Mathematica, MATLAB, and ARCGIS.

Keith Guenther of Wildland Solutions is a licensed Certified Rangeland Manager who has developed landcover data, grazing management plans and monitoring plans for private ranches, public agencies and non-governmental organizations including the Nature Conservancy, California State Parks, U.S. Army and the U.S. Forest Service. Keith established Wildland Solutions (www.wildlandsolutions.com) in 1997 to provide services specializing in wildlife/livestock management interactions including environmental assessments, analysis, grazing plans, monitoring plans and expert testimony in court cases. He has accomplished this by developing techniques for integrating ground surveys and remote sensing data using GIS. Keith has conducted rangeland vegetation surveys and prepared management plans in several western states including Arizona, New Mexico, Idaho, Washington, Oregon and California. Management plans are designed according to “Adaptive Management” concepts that incorporate monitoring in a cost effective manner, allowing the land manger to document successful management strategies and identify what needs to be modified. Keith Guenther has a unique combination of expertise in both planning and implementation of complex and often controversial natural resource projects which provides an ability to successfully work with interdisciplinary teams, clients and agency personnel. Mr. Guenther’s extensive technical and practical experience in rangeland ecology, land management planning and successful administration of grazing and wildlife programs on private and public lands provides the ability to identify appropriate project goals, analyze issues and develop integrated solutions that are creatively tailored to each project.

Lynsey Parker is an Associate at ENVIRON, is an environmental analyst specializing in air quality modeling, GIS and emissions processing. She utilizes GIS to produce Gridded Emission Inventories such as Commercial Marine Vessel (CMV) inventories. Lynsey developed CMV emissions inventories in a gridded format for use by the EPA in recent modeling in support of proposing a Sulfur Emissions Control Area, about 200nm around the US coastline. She developed the gridded emissions with GIS tools using Arc Macro Language (AML) and PERL programming. She created many different CMV emission scenarios in support of EPA modeling to determine the range of AQ improvement under different emissions reduction scenarios. Lynsey utilizes GIS on an almost daily basis for various map-making and spatial-analytical tasks, including creating source apportionment maps for CAMx modeling, and defining AQ modeling domain regions, data reprojecting/reformatting (i.e. changing coordinate systems), and map creation for visual representation of data. In addition she has experience with emissions modeling using the Sparse Matrix Operator Kernel Emissions (SMOKE) emissions model. Lynsey is also knowledgeable in FORTRAN, PERL, and Visual Basic.

Piti Piyachaturawat is an associate at ENVIRON International Corporation's Air Sciences office in Novato, California. He is an environmental engineer specializing in statistical analysis, database design and development, and optimization modeling. He has experience using MM5 model and Metstat for meteorological data processing and has performed numerous pre- and post-processing tasks for CAMx, CMAQ, and AERMOD model. In addition, he has been involved in modification and development of GloBEIS and Chemical Process Analysis (CPA) mechanisms for CAMx model. Piti is proficient in various programming languages including Perl, FORTRAN, Linux Cshell, SQL, and Visual Basic. He is also comfortable working with databases through Access, and is skilled at using spreadsheet packages.

Ralph Morris is the Managing Principal of ENVIRON's Novato California Office where he directs air quality modeling and analysis, control strategy development and evaluation, and regulatory air issues projects. Ralph is the proposed Project Manager and Co-Principal Investigator for the Denver 8-hour ozone modeling study, a position he held in the previous Denver 2008 and 2003 8-hour ozone SIPs. He has over 31 years experience in air quality issues, with particular emphases in the development and application of advanced air quality models and the development of air quality emission control plans. He has directed or was one of the key developers of many of the photochemical grid models that have been used to develop ozone attainment State Implementation Plans (SIPs) in the U.S., including the UAM, UAM-V, and CAMx. Ralph has led, or been involved in, the development of ozone SIPs for numerous areas including: Los Angeles, San Francisco, Houston/Galveston, Dallas-Fort Worth, Denver; Oklahoma; New Mexico; St. Louis; and southeastern states. . Ralph was one of the Co-PIs in the Western Regional Air Partnership (WRAP) Regional Modeling Center (RMC) performing regional fine particulate and visibility modeling using the CMAQ and CAMx models. Ralph was also Project Manager for the Regional Haze and ozone/PM modeling activities of the Central States (CENRAP) and Southeastern States (VISTAS/ASIP). Ralph was an original member of EPA's ozone guidance workgroup (formed in 1990) and was a founding member of the CMAS Models-3/CMAQ External Advisory Committee (EAC). He is currently a member of the Peer-Review Modeling Group for the South Coast Air Quality Management District (SCAQMD) and the Air Quality Modeling Subcommittee (AQMS) of EPA's Science Advisory Board (SAB).

3.2.3 Project Qualifications

Personnel in the ENVIRON/Alpine Team have been operating photochemical grid models for over 30 years. Consequently, the ENVIRON/Alpine Team has performed thousands of successful studies related to the Denver 8-hour ozone modeling study. The RFP requests that we provide a list of previous and current contacts for studies of a similar nature. Given the extensive experience of the ENVIRON/Alpine Team listing of all relevant studies would be exceed the page limit of this proposal. Thus Table 3-1 lists some of the most recent relevant projects that the ENVIRON/Alpine Team have performed, including the contact, location and contract duration. The project summaries in Table 3-1 are broken down into three categories, with the first two corresponding to the first two evaluation categories in the RAQC Denver modeling RFP:

Table 3-1. Relevant project experience.

Project Title and Description	Client Contact, Affiliation, Phone
Biogenic Emissions Model Development and Evaluation	
MEGAN development	
Evaluation of Biogenic Emission Models using TexAQSII Aircraft Data. Dr. Tan Sakulyanontvittaya of ENVIRON and Dr. Alex Guenther collaborated on a project for the TCEQ to evaluate predictions by the MEGAN and GloBEIS biogenic emission models using isoprene concentration data collected by the NOAA P3 aircraft during the TexAQSII field study in 2006.	Mark Estes, TCEQ (512) 239-6049
Biogenic Field Study for Phoenix, AZ. Dr. Greg Yarwood of ENVIRON and Dr. Alex Guenther collaborated on a biogenic emissions field study and emissions model development study for Phoenix, AZ on behalf of the Maricopa Association of Governments (MAG). Field measurements characterized emission factors and plant species distributions for vegetation characteristic to the Phoenix area. GIS analyses characterized land cover. Field study data were implemented in a database version of the MEGAN model that was used by MAG for ozone SIP modeling.	Taejoo Shin, MAG (602) 254-6300
Improved Biogenic Emission Model for Alberta. ENVIRON improved the land cover input data to MEGAN for Alberta by using local Alberta and Canada satellite-landuse data and ENVIRON developed gridded biogenic emissions for CMAQ modeling for 2003-2006 years.	Yayne-abeba Aklilu, AENV. (780)644-5039
Developing the GloBEIS Biogenic Emissions Model. Dr. Greg Yarwood of ENVIRON and Dr. Alex Guenther collaborated on several projects for TCEQ to develop the GloBEIS biogenic emissions model (www.globeis.com). GloBEIS implements BEIS3 emission algorithms in a database framework that facilitates input of local land cover and emission factor data. Field studies were conducted in Texas to collect locally specific vegetation data. Model algorithms were implemented to account for seasonal variation in LAI and response to drought and periods of extended heat.	Mark Estes, TCEQ (512) 239-6049
Developing and Evaluating the MEGAN emission model. Dr. Alex Guenther is leading laboratory and field studies to characterize factors controlling biogenic VOC emissions. The observations are being used to develop and evaluate improved modeling procedures that can be used for regulatory air quality modeling in the U.S. and elsewhere. Current efforts are focused on the Model of Emissions of Gases and Aerosols from Nature (MEGAN).	**Chris Geron, USEPA** NRMRL, **(919) 541-4639**
Improving Regional Biogenic VOC Emission Estimates using an Airborne PTRMS Eddy Flux Measurement System. Dr. Alex Guenther is collaborating with Dr. Allen Goldstein of UC Berkeley to deploy an airborne flux system to directly measure regional fluxes of biogenic VOC and use the results to evaluate and improve biogenic VOC emission models.	Ash Lashgari California ARB 916 323-1506
MEGAN and BEIS3 intercomparison and evaluation. Dr. Alex Guenther is conducting an evaluation and intercomparison of BEIS3 and MEGAN models by conducting field and laboratory studies to characterize individual components of these biogenic emission models including emission algorithms (e.g. emission response to temperature and light), emission factors, and canopy environment.	National Science Foundation
Air Quality Modeling Projects in the Rocky Mountain West	
Rocky Mountain Organic Carbon Study. Dr. Alex Guenther is leading a field study to characterize biogenic VOC emissions along the front range of the Rocky Mountains and quantify the impact of these emissions on oxidants and secondary organic aerosol.	National Science Foundation
WGA WestJump Project. ENVIRON is leading the WestJump Air Quality Modeling Study to develop 2008 annual air quality modeling databases for 36, 12 and 4-km grids focused on the Western US. The first activities will be meteorological and emissions modeling to prepare input data for subsequent air quality modeling.	Tom Moore, WGA (970) 491-8837

Project Title and Description	Client Contact, Affiliation, Phone
WRAP Regional Modeling Center (RMC). ENVIRON was part of the Western Regional Air Partnership (WRAP) Regional Modeling Center (RMC). The WRAP RMC has set up and run the SMOKE emissions and CMAQ and CAMx air quality models on a 36/12 km domain to address visibility degradation at sensitive Class I areas throughout the west.	Tom Moore, WRAP (970) 491-8837
Denver 8-Hour Ozone SIP Modeling. ENVIRON and Alpine Geophysics performed MM5 meteorological, SMOKE emissions and CAMx photochemical modeling on a 36/12/4 km domain and a June-July 2006 episode to support the development of the 2008 Denver ozone SIP. Detailed mobile source emission inputs were generated for Denver using link-based VMT data from a travel demand model (TDM) and the CONCEPT MV emissions model. Under extreme time constraints, ENVIRON/Alpine completed the Denver 2008 SIP hour ozone attainment demonstration modeling in August 2008 so that the Colorado 8-hour ozone SIP is on track to be completed in 2008. As a follow on to the Denver SIP modeling, ENVIRON/Alpine performed modeling of the 2015 and 2020 years to address compliance with the new (March 2008) 0.075 ppm 8-hour ozone NAAQS.	Jerry Dilley Denver RAQC (303) 629-5450x240
Four Corners Air Quality Task Force Modeling. ENVIRON, and subcontractor Alpine Geophysics, performed emissions and air quality modeling of the western U.S. for the Four Corners Air Quality Task Force (FCAQTF). The FCAQTF were concerned that increased oil and gas (O&G) development in the region could endanger the new 8-hour ozone NAAQS and cause visibility and deposition impacts at nearby Class I areas. ENVIRON/Alpine set up the MM5/SMOKE/CAMx modeling system on a 36/12/4 km grid for the 2005 calendar year. Emissions were projected to 2018 and various 2018 emissions mitigation scenarios were analyzed to assess their effects on ozone, PM, visibility and deposition.	Rita Trujillo New Mexico ED (505) 827-1494
BLM Grand Junction RMP Air Quality Assessment. ENVIRON is performing the air quality and air quality related values (AQRV) for the Resource Management Plan (RMP) revision for BLM's Colorado Grand Junction Field Office (GJFO). Working closely with the GJFO and State of Colorado BLM Office, ENVIRON has prepared a Modeling Protocol that discusses how development in the GJFO area will affect air quality and AQRV in the region. In particular, the effects of oil and gas development, off terrain vehicle (OTV) and other uses impacts on air quality will be investigated.	Matt Anderson, BLM Grand Junction (970) 244-3027
Uinta Basin Air Quality Study. ENVIRON performed the Uinta Basin Air Quality Study (UBAQS) to address the cumulative air quality and air quality related values due to oil and gas development activities throughout the Uinta Basin and nearby areas. The CMAQ model was used to simulate the 2005 and 2006 annual periods for a 12 km domain covering eastern Utah and western Colorado and a model performance evaluation conducted. Simulations were then conducted for a 2006 baseline and a 2012 future year.	Kathleen Sgamma Western Energy Alliance (303) 623-0987x226
WRAP/IPAMS Phase III Oil and Gas Emissions Inventory. ENVIRON is conducting a comprehensive emissions inventory development project jointly sponsored by the Western Regional Air Partnership (WRAP) and the Independent Petroleum Association of Mountain States (IPAMS). The project, known as Phase III, builds from two earlier region-wide oil and gas inventory projects sponsored by WRAP. The Phase III project is the most comprehensive regional inventory conducted to date of all oil and gas activity including major and minor sources of all criteria pollutants in the Rocky Mountains.	Tom Moore Western Governors Association (970) 491-8837
Piceance Pilot Project (P3) Study of Oil and Gas Mobile Source Emissions. ENVIRON is working under contract to the U.S. EPA to study on-road and off-road mobile source emissions associated with oil and gas activity in the Piceance Basin in Northwestern Colorado. The project is directed by a technical steering committee composed of WRAP staff, environmental staff from Colorado and Wyoming, and industry participants. ENVIRON is developing a 2009 first-of-its-kind emissions inventory of oil and gas mobile sources, including trucking, construction and maintenance equipment, and commute vehicles associated with oil and gas development activities.	Scott Jackson U.S. EPA Region 8 (303) 312-6107
BLM Continental Divide-Creston EIS Natural Gas Project. ENVIRON is performing the air quality and AQRV assessment of the Continental Divide-Creston (CD-C) oil and gas (O&G) infill project for the BLM Rawlins Field Office. The CD-C O&G infill project plans to drill over 10,000 wells in an area in Sweetwater and Carbon Counties, Wyoming. The effects of the CD-C O&G development will be assessed for ozone and other criteria pollutants, visibility and deposition as well as green house gases (GHG). The ozone issue is particularly important given that some areas in southwestern Wyoming are currently violating the ozone NAAQS.	Eldon Allison BLM Rawlins (307) 328-4267 https://webapp2.nbc.gov/blm/BLMConta.nsf/44816574678f73bc8525761f004dd42a/c271c119c23861c98725775800268 0f3?OpenDocument
BLM Moxa Arch O&G Gas Infill Project EIS. ENVIRON is performing the AQ and AQRV assessment of the Moxa Arc O&G infill development project in Sweetwater, Lincoln and Uinta Counties, Wyoming. An initial assessment of the AQ/AQRV impacts was performed using the CALPUFF modeling system for the far-field and AERMOD model for the near-field. The CAMx photochemical grid model is currently being applied to estimate the ozone impacts due to the Moxa Arch project as well as a replacement to CALPUFF for the far-field modeling.	Michele Easley BLM Kemmerer (307) 828-4524 https://webapp2.nbc.gov/blm/BLMConta.nsf/44816574678f73bc8525761f004dd42a/b9ffb1cb1986f81387257758002690 59?OpenDocument

Project Title and Description	Client Contact, Affiliation, Phone
BLM Hiawatha Regional Energy Development Project EIS. ENVIRON is performing the AQ and AQRV assessment for the Hiawatha Energy Development EIS project. The Hiawatha project area straddles the Wyoming –Colorado state line and resides in Sweetwater County, Wyoming and Moffat County, Colorado. The CAMx photochemical grid model is being applied to assess the ozone impacts as well as the far-field AQ and AQRV impacts of the proposed project.	John McDonald BLM Rock Springs (307) 352-0238
GMI/Beaver Creek O&G EIS Studies. The Gun barrel-Madden-Iron horse Natural Gas and Beaver Creek Coal Bed Natural Gas (CBNG) projects were combined into a single EIS due to their proximity to each other. The GMI/Beaver Creek O&G development projects reside in Fremont and Natrona Counties in central Wyoming. In addition to the usual ozone, other criteria pollutants and near-source and far-field AQ and AQRV issues associated with O&G development in Wyoming, the GMI project has sour gas that raises new issues to address.	Jim Cagney BLM Lander (307) 332-8400
BLM Little Snake RMP Air Quality Assessment. ENVIRON conducted the AQ and AQRV modeling for the Colorado Little Snake Field Office Resource Management Plan (RMP) revision. The AQ and AQRV impact due to potential resource development in the Little Snake FO area was assessed using the CALPUFF model. ENVIRON assisted the Little Snake Field Office and their third party contractor (Booz-Allen) in the preparation of the RMP.	Jeremy Casterson BLM Little Snake (970) 826-5071 Colorado 2007-2008
Pinedale Anticline Oil and Gas Infill Project EIS. ENVIRON performed ozone modeling using the CAMx photochemical grid model to assess the potential ozone impacts of the Pinedale Anticline oil and gas development project.	Lauren McKeever BLM Pinedale (307) 367-5352
Chapita Wells O&G EIS Project. Alpine Geophysics and ENVIRON are performing the air quality and AQRV impact assessment of the Chapita Wells oil and gas development project in the Uinta Basin, Utah. Alpine is a subcontractor to the Petros Environmental Group who is leading the development of the Chapita Wells EIS.	Joe Fetzer Petros (303) 798-2669

3.3 COMPUTER FACILITIES

The Novato office of the Air Science Group has substantial computing capabilities, allowing for the efficient use of the most sophisticated meteorological, emissions, and air quality models. Our computer center includes the very latest computing technology including both OMP (shared memory) and MPI (distributive memory) multi-processing capability. All staff also have their own state-of-the-art PCs, which typically include a Windows-based PC as well as a Linux-based PC, and have access to all workstations at all times. This structure ensures that there are no limitations with computer resource availability. ENVIRON's high speed Linux computing environment includes a variety of Linux workstations including Dual Hex-Core and Dual Quad-Core Linux workstations (over 150 processors total) that form the bulk of the meteorological and photochemical modeling resources. These machines can be utilized as stand-alone workstations but are also connected via a fast private LAN to facilitate distributive parallel processing. The ENVIRON Linux computing environment also includes a number of support workstations that are typically used for modeling related tasks, such as emissions inventory processing, model input preparation and model post-processing. Over 30,000 Gbytes (30 Terabytes) of disk storage are available to the Linux workstations on data protected RAID systems. All of the workstations are networked together and are accessible from each employee's desktop PC. All workstations have CD-ROM drives and can access external disk drives (firewire and USB2) for data backup and data transfer. ENVIRON can also create CDs (CD-R and CD-RW) and DVDs (DVD±R and DVD±RW) for data backup and distribution.

The Novato office of The Air Science Group has up-to-date software, programs, programming libraries and compilers, and various in-house tools which can facilitate emission estimates, air quality modeling, and air quality analysis. Most emission inventory works require geographic information system (GIS) tool to visualize, allocate, and analyze spatial data. For this project, we, Novato office and NCAR, will use the latest release ARCGIS 10 by ESRI. This release is

compatible with Windows 7 operating system and compatible backward to PYTHON GIS batch scripts or ARC Macro Language created in earlier release. This means we, Novato office and NCAR, are fully compatible and capable of any spatial analysis and batch processes.

4.0 References

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Appendix A

Resumes