Drill Rig 1-hour Nitrogen Dioxide (NO_2) Impacts and Model Evaluation Study

Summary Report

May 10, 2016

Background:

The Environmental Protection Agency's (EPA's) AERMOD model is one of several dispersion models used by regulatory agencies and industry to evaluate air quality impacts from stationary sources, including compliance with the 1-hour Nitrogen Dioxide (NO_2) National Ambient Air Quality Standard (NAAQS). Due to the temporary and intermittent emissions associated with oil and gas drilling activities, there are currently no data sets evaluating AERMOD's performance for this application. Consequently, it is not known how accurately AERMOD and conversion factors/methods predict 1-hour NO_2 impacts from oil and gas drilling activities. Therefore, a collaborative effort by the Bureau of Land Management (BLM) and the American Petroleum Institute (API), partnering with EPA, States, other Federal Land Managers, and Oil and Gas operators was designed and implemented to collect both emissions data and simultaneous ambient measurements at and adjacent to operating drilling rigs. The data facilitate the evaluation of performance of AERMOD and other dispersion models in assessing 1-hour NO_2 impacts from drilling operations. The "Drill Rig 1-hour NO_2 Impacts and Model Evaluation Study" consists of a collaborative effort to collect, review, and process emissions, ambient, and meteorological data; assess model performance; and make recommendations for model improvement. Funding for the field study and data evaluation efforts to date was provided by ConocoPhillips, the BLM, the API, and the EPA, with important in-kind contributions by the States of Alaska, Colorado, Montana, Utah, Wyoming, the BLM Utah State Office, and EPA's Office of Air Quality Planning and Standards (OAQPS).

Study Management:

To provide direction and guidance for the "Drill Rig 1-hour NO_2 Impacts and Model Evaluation Study" the study participants formed a "Study Management Team". The Study Management Team included the following:

- Mary Uhl (BLM New Mexico State Office), after January 2016, Craig Nicholls (BLM National Operations Center)
- Chris Owen (EPA OAQPS; Owen.Chris@epa.gov)
- Darla Potter (Wyoming Department of Environmental Quality; darla.potter@wyo.gov)
- Cathe Kalisz (API; kaliszc@api.org)
- Doug Blewitt (Consultant to API)

The Study Management Team can be contacted at the email addresses provided above. In addition, the following representatives of the Western States Air Resources Council (WESTAR) and the Western Regional Air Partnership (WRAP) provided overall administrative and other assistance to the Study Management Team.

- Tom Moore (WRAP Air Quality Program Manager; tmoore@westar.org)

- John Bunyak (Consultant to WESTAR-WRAP)

Field Studies:

The NO_2 impacts and model evaluation study included collecting onsite data during two field study-sampling programs at three separate drill rig sites. One field study was conducted over a six-week period in October 2014 and November 2014 at two Anadarko Petroleum Corporation well pads in the Denver-Julesburg Basin near the town of Platteville, Colorado. The second field study was conducted from August 22, 2014, through December 31, 2014, at a ConocoPhillips Alaska drilling rig located in the Kuparuk River Unit on the North Slope of Alaska.

Denver-Julesburg Field Study Design

The Denver-Julesburg fieldwork was carried out by URS Corporation[1] under a contract with WESTAR. The approach for the field study consisted of the following data collection activities (for both 5-minute and 1-hour averaging periods):

- Continuously monitor NO_x, NO, and NO_2 emissions from the three diesel engines that power the drilling rig;
- Continuously monitor CO_2, O_2, temperature, and pressure of the engine exhaust;
- Continuously monitor levels of NO and NO_2 in the near-field ambient air at 12 sites upwind, downwind, and crosswind to the drilling rig;
- Continuously monitor levels of O_3 in the ambient air at one upwind and one downwind site; and
- Continuously monitor wind speed, wind direction, and additional meteorological parameters at one upwind and one downwind site and on a 10-meter instrumented tower.

The Colorado field study was originally designed for 30 days of data. However, the monitoring start-up was delayed and the drilling at Site 1 was completed sooner than expected, resulting in only 18 days of data. Consequently, the rig moved about 0.5 miles to the west of Site 1, and the monitoring was extended an additional two weeks at Site 2 to get the full 30 days of data.

The emissions data for the rig include measurements from three diesel-fired electric generators that operated at Site 1, and the same three generators and a boiler that operated at Site 2. Two of the electric generators were Caterpillar 3512B engines rated at 1,475 bhp each, and the other was a Caterpillar C27 engine rated at 1,150 bhp. The boiler was rated at 6.3 MMBtu/hr.

The ambient monitors at both Sites 1 and 2 were mounted on 12 portable trailers to facilitate moving the monitors as needed throughout the study periods. URS/AECOM conducted some preliminary AERMOD modeling using nearby Greeley-Weld airport meteorological data for the years 2009-2013 to help determine the initial monitor placement. The AERMOD results showed that the peak modeled NO_x concentrations were located inside the drill pad. The October sampling period was characterized by warmer than normal conditions with light winds and limited dispersion off the well pad. As the sampling continued into November, temperatures fell very quickly to near record lows and wind speeds and dispersion increased. For Site 1, the monitors were positioned near the pad boundary based on predominant winds, but were not relocated due to airflow obstructions, off-pad access limitations, and power constraints. For Site 2, the monitors were repositioned based on prevailing wind forecasts, but were limited to near the well pad boundaries, again due to off-pad access limitations and power constraints (See Summary of Colorado Field Study (PPTX) for specific monitor placements.)

[1] In October 2014, as this project was being implemented, AECOM completed a financial transaction to acquire URS. The formerly two companies are now integrated as one and go by the name of "AECOM".

Upon completing the field sampling, URS/AECOM prepared a report that describes in detail its technical approach for the monitoring, and includes all of the data gathered, along with supporting documentation such as calibration records, quality assurance documents, plot plans, field logbook, etc. All of these data and supporting documentation have been archived for further analysis as the study proceeds.

WESTAR then granted a contract to AMEC Foster Wheeler (AMEC) to review and format the Denver-Julesburg data. AMEC reviewed the collected 5-minute and 1-hour averaged continuous emissions monitoring data, ambient pollutant data, meteorological data, calibration records, and other Quality Assurance documents from the Denver-Julesburg Field Study. Based on AMEC's findings of its data quality review, AMEC updated the 5-minute and 1-hour Denver-Julesburg emissions, ambient pollutant, and meteorological data to address the following:

- Duplicate records in the 5-minute data
- 1-hour averages not consistent with 5-minute data
- Erroneous measurement values flagged as valid
- Status flags not consistent with calibration records
- Treatment of negative emissions and ambient pollutant concentrations
- 1-hour boiler temperature and pressure data stored in incorrect fields (Site 2 only)

After updating the appropriate data files, AMEC provided time-series and scatter plots of the updated data that provide improved visual analysis of the data. AMEC also began to format the Denver-Julesburg meteorological data for use with the AERMOD model. AMEC provided a report that documents its review of the Denver-Julesburg data (PDF), along with electronic file attachments of the updated data and related work. Again, this report, the updated data files, and supporting documentation have been archived for further analysis as the study proceeds.

Kuparuk River Unit Study Design

With funding provided by ConocoPhillips Alaska, the Kuparuk River Unit Field Study was conducted from August 22, 2014, through December 31, 2014, at ConocoPhillips Alaska's Nabors 9ES drill pad. The Nabors 9ES rig has two Caterpillar 3512B engines rated at 1475 bhp each, one Caterpillar 3412 engine rated at 831 bhp, two 150 hp boilers, and a total heater capacity of 2.96 MMBtu/hr. The 3512B engines ran in parallel sharing the load for power generation. The 3412 engine was used as a "move engine" and only operated when moving from one well to another. It did not operate during drilling activities. The two boilers heated the rig, and the heater warmed the pipe shed. Continuous Emission Monitoring Systems (CEMS) were deployed on the drill rig to measure emissions from the two 3512 B engines, the two boilers, and the heater.

The ambient monitoring network, site configuration and monitors deployed were more limited than in Colorado, due to operational and access limitations. An ambient air quality monitoring station was deployed downwind to monitor potential impacts originating from the rig operations. An additional upwind ozone sampler was operated to measure ozone concentrations entering the local study area. (See Alaska Field Study Status Report – December 2014 (PDF)). Fuel usage of the engines, boilers, and heater was also monitored. Meteorological parameters were monitored at the site, as well as at a nearby site. Specifically, the following parameters were monitored as part of the Kuparuk River Unit Field Study (for both 1-minute and 1-hour averaging periods):

- Source Measurements (stack O_2, NO_x, NO, NO_2 emissions)

- Fuel Usage
- Ambient Air Quality Measurements (NO_x/NO/NO_2, SO_2, $PM_{2.5}$, PM_{10}, CO, O_3)
- Meteorological Measurements
    - Onsite monitoring station (wind speed, wind direction)
    - 10-meter meteorological tower located nearby at the Kuparuk/DS1F drill pad
        - Wind speed and direction at 10 meters;
        - Sigma theta (calculated via the Yamartino method);
        - Temperature (2 meter, 10 meter, and differential temperature/delta T);
        - Solar radiation;
        - Vertical wind speed;
        - Solar Radiation;
        - Relative Humidity; and
        - Barometric Pressure
- Photo time series available for the entire operating period

As with the Denver-Julesburg data, the Kuparuk River Unit Field Study data have been archived for further analysis as the study proceeds.

As part of the AMEC data review contract discussed above, AMEC also performed an initial cursory review of the Kuparuk River Unit Field Study data. The purpose of this cursory review was to inspect the data files to determine if there were any obvious errors in the data that will need to be resolved or any obvious omissions in the data, monitoring records, or other documentation that are needed to perform a more detailed quality assurance review and subsequent analyses of the monitoring data. After its cursory review, AMEC concluded that there were no obvious errors or omissions in the Kuparuk River Unit Field Study data, but there were some minor inconsistencies between the data and supporting documentation. However, AMEC reported no findings that would preclude a more detailed review of these data.

Subsequent to AMEC's cursory review of the Kuparuk River Unit data, WESTAR modified the AMEC data review contract to allow AMEC to perform a more thorough review and analysis of the Kuparuk River Unit data. The Scope of Work for this additional review included: (1) calculating hourly mass emission rates and emission velocities; (2) performing specific data analyses; (3) formatting the hourly data for AERMOD model evaluation; (4) researching the availability of nearby offsite meteorological data; (5) constructing a modeling database; and (6) preparing a report to summarize and document AMEC's approach and assumptions made. AMEC focused its review of the Kuparuk River Unit data to the creation of an AERMOD-ready model evaluation dataset that includes: 1) hourly onsite meteorological data formatted for input to AERMET, the meteorological preprocessor for AERMOD; 2) an hourly NO_X emissions file formatted for input to AERMOD; 3) an hourly background ozone file formatted for input to AERMOD; and 4) building downwash parameters formatted for input to AERMOD (i.e., generated with BPIPPRM). AMEC completed its review on May 3, 2016. (PDF)

Model Evaluation Workgroup

To further process the Denver-Julesburg and Kuparuk River Unit field studies data and to conduct the modeling to assess AERMOD and other model performance compared to the collected data, the Study Management Team formed a "Model Evaluation Workgroup". The workgroup conducted a "kick-off" meeting on August 14, 2015, at EPA's office in Research Triangle Park, North Carolina. At this meeting, background and summary information regarding the two field studies was presented, and recommendations for further analysis, covering both the data review and model evaluation phases of the study, were discussed. The materials presented and discussed at the meeting can be found on the Drill Rig 1-hour NO_2 Impacts and Model Evaluation Study webpage and the meeting summary are available here.

To solicit a broad participation in the Workgroup, the Study Management Team reached out to State/Federal/Industry contacts and various groups, including the WESTAR Technical and Planning Committees, the National Association of Clean Air Agencies, and the Association of Air Pollution Control Agencies, to seek member participation in the Workgroup. Additional participation in the Workgroup and the Analysis Teams listed next is welcome.

The Model Evaluation Workgroup has been organized into four Analysis Teams, each with a list of suggested topics and tasks for moving the study forward. These four Teams include:

- Ambient data analysis team (Team Leader: Leiran Biton, EPA, Region 1; biton.leiran@epa.gov);
- Dispersion modeling team (NO_x/CO/SO_2 focused) (Team Leader: Rebecca Matichuk, EPA Region 8; matichuk.rebecca@epa.gov);
- NO_2 modeling analysis team (NO_x chemistry focused) (Team Leader: Chris Owen, EPA OAQPS; owen.chris@epa.gov); and the
- Model/monitor data evaluation team (Team Leader: Clint Bowman, Washington Department of Ecology; clint@ecy.wa.gov)

The work of these teams is ongoing.

Next Steps

The Study Management Team will continue its efforts to seek additional funding for contractor assistance with the Drill Rig 1-hour NO_2 Impacts and Model Evaluation Study. Continued consulting services to assist the work of the various Teams would be very beneficial moving forward. AMEC has submitted a cost proposal to the Study Management Team for additional, more thorough review and analysis of the Denver-Julesburg data as was done for the Kuparuk River Unit data. While funding opportunities are explored, the Teams of the Model Evaluation Workgroup, with EPA taking a leadership role, will continue to review and format the field study data, fill in any needed data gaps, and conduct model evaluations to assess the performance of AERMOD and other models compared to the collected data. Once this work is complete, the Workgroup will summarize and document its findings and conclusions, perhaps in technical journal articles, and then submit recommendations to the EPA for making improvements to applicable regulatory dispersion models. A target date for completing the study is December 2017.

Resources (from Study website at http://www.wrapair2.org/DrillRig.aspx**)**

- Study Organization call – November 2013 (PDF)
- Company Assistance Needed for Ambient Air Quality NO2 Drill Rig Field Study Program – May 2014 (PDF)
- Drill Rig 1-hour NO2 Emissions and Air Quality Study Outreach - May 2014 (PDF)
- Collaborative Drill Rig 1-hour NO2 Impacts Study presentation – EPA/State/Local Modelers Meeting – May 2014 (PPTX)
- WESTAR RFP #2014-01 for Drill Rig NO2 Monitoring Project – June 20, 2014 (PDF)
  - Questions and answers from pre-proposal call about WESTAR RFP #2014-01 – June 28, 2014 (PDF)
- Alaska Field Study Design - Drill Rig 1-Hour NO2 Collaborative Study - August 2014 (PDF)
  - Alaska Field Study Status Report – December 2014 (PDF)
  - Alaska Dept. of Environmental Conservation Review of Alaska Study CEMS data - October 28, 2015 (PDF)

- Denver-Julesburg Field Study Status Report – December 2014 (PDF)
  - Denver-Julesburg Field Study Quality Assurance Project Plan - October 2014 (finalized April 2015) (PDF)
  - Denver-Julesburg Field Study Contractor Report - April 2015 (PDF)
  - Contractor Report on Data Review - July 2015 (PDF)
- Drill Rig Study Model Evaluation Workgroup
  - Kick-off Meeting; RTP, NC - August 14, 2015
    - Meeting Agenda (PDF)
    - Summary of Colorado Field Study (PPTX)
    - Summary of Alaska Field Study (PPTX)
    - Summary of Contractor Report on Data Review (PPTX)
    - Suggested Analyses of CO and AK drill rig data (PPTX)
    - Meeting Summary (PDF)
  - Summary of September 3, 2015 Workgroup Conference Call (PDF)
  - Summary of October 8, 2015 Workgroup Conference Call (PDF)
  - Model Evaluation Workgroup Teams (PDF)