Session 1: Overview of NEPA Air Quality Analysis for Highway Projects

NEPA Law and Regulations

• National Environmental Policy Act of 1969
• Council on Environmental Quality NEPA regulations
  – 40 CFR 1500 – 1508
• FHWA/FTA joint NEPA and Environmental Impact regulations
  – 23 CFR 771
• All can be found on the FHWA Environmental Review Toolkit website
FHWA’s NEPA Documents are Environmental Compliance Documents

- Federal agencies must consider the environmental consequences of their actions
- FHWA uses NEPA to document compliance with all applicable environmental laws
- NEPA is the framework for interagency coordination
- NEPA is the framework for meaningful public involvement

Key Elements of NEPA

- Purpose and Need
- Range of Reasonable Alternatives
- Impacts
- Mitigation
- Public Involvement and Interagency Coordination
- Documentation
NEPA Air Quality Analysis

- Components (not all are completed for every project):
  - Information on the NAAQS (table)
  - Description of existing conditions (air quality, meteorology)
  - Status of State Implementation Plans for the area
  - Comparison of corridor emissions for no-action and build alternatives (qualitative or quantitative inventory analysis)
  - Microscale analysis (CO and/or PM; qualitative or quantitative)
  - Qualitative or quantitative analysis of mobile source air toxics
  - Qualitative or quantitative analysis of GHGs
  - Cumulative/indirect effects analysis
  - Mitigation
Technical Analysis for NEPA: Applicability

- Inventory analysis (criteria pollutants: CO, PM, ozone precursors)
  - Not required by any guidance, but often completed for large projects
- Microscale analysis for CO
  - 1987 TA: CO hotspot modeling recommended for large projects
- Qualitative or quantitative analysis of mobile source air toxics
  - Required by FHWA guidance (more later)

Technical Analysis for Conformity: Applicability

- Transportation conformity rule hot-spot requirements apply in nonattainment and maintenance areas for CO, PM10/2.5
- If the area is nonattainment/maintenance for multiple pollutants, multiple analyses may be needed
- No hot-spot or other analysis is required at the project level for ozone
- Conformity determination required prior to NEPA process completion (CatEx, FONSI, ROD)
Technical Analysis for Conformity: Applicability

• The NEPA document should clearly identify which analyses are being conducted to support a conformity determination, and which are being conducted only for NEPA purposes
• All analyses used to satisfy Clean Air Act conformity requirements should follow the Transportation Conformity regulation (40 CFR Part 93) and associated guidance

Background Information

• Information on the NAAQS (table)
• Description of existing air quality, including nonattainment/maintenance/attainment status
• Status of State Implementation Plans for the area
• Description of meteorology
Many large projects include an inventory analysis in the NEPA document, which is a corridor-level emissions analysis

– Required for MSATs for some projects, sometimes also done for criteria pollutants

Example:

<table>
<thead>
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<td>CO</td>
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<tr>
<td>Benzene</td>
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<tr>
<td>Butadiene</td>
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<tr>
<td>Acrolein</td>
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Reference Materials for NEPA Air Quality Analysis

– Air Quality section of 1987 Technical Advisory
– December 2012 Interim MSAT Guidance (update of 2006 and 2009 guidance)
– FHWA Environmental Guidebook:
Hot-Spot Analysis for Transportation Conformity

Project Level Conformity – General

- Project-level conformity analyses and hot-spot analysis documentation often appear in the environmental document
  - Meeting transportation conformity requirements is a very involved process which will not be covered in detail in this course
- Training on project-level conformity is available at:
  - http://www.fhwa.dot.gov/environment/air_quality/conformity/training/
The Clean Air Act prohibits the Federal government from approving or funding any activity (including transportation projects) which does not conform to State Implementation Plan.

Conformity applies in nonattainment and maintenance areas for the transportation-related NAAQS.

These areas are designated by EPA, and listed on EPA’s Green Book web site:
- www.epa.gov/oar/oaqps/greenbk/

The project comes from a conforming plan and TIP:
- Including any necessary written commitments for project-level emissions mitigation or control measures (any included in TIP project design concept and scope).

The design concept and scope have not changed significantly since the conformity finding regarding the plan and TIP from which the project derived.

Analyses use latest planning assumptions and latest emissions model.

40 CFR §93.114-117
General Project-Level Conformity Requirements

- Includes a hot-spot analysis in CO and PM nonattainment and maintenance areas, if required
- Compliance with control measures in PM SIP

Hot-Spot Analysis for Conformity

- Required for Federal nonexempt projects in CO, PM2.5, and PM10 nonattainment and maintenance areas
  - applicability depends on type of project
- EPA quantitative hot-spot guidance
  - Guidance for use of MOVES2010b in CO hotspot analysis issued December 2010
  - PM hotspot guidance updated November 2013
  - MOVES model required for quantitative PM and CO hot-spot analyses begun after 12/20/12

www.epa.gov/otaq/stateresources/transconf/projectlevel-hotspot.htm
What Projects are Subject to CO Hot-spot Analysis?

- Modeling required for:
  - Projects that impact a location identified in the SIP as a site of actual or possible violations
  - Projects that affect intersections that are or will be LOS D or worse
  - Projects affecting one of the 3 worst intersections in the area in terms of traffic volume or LOS
- Qualitative analysis required for all other projects

Categorical Hot-spot Finding for CO

- Modeling conducted by U.S. DOT that shows particular category of highway or transit projects will not cause or contribute to new or worsened local violations
- Potential for project sponsor to streamline meeting the CO hot-spot requirements, since no additional quantitative hot-spot modeling would be required
  - Compare project to scenarios modeled by U.S. DOT to see if it is covered by the categorical finding
Categorical Hot-spot Finding for CO

- A project-level conformity determination is still required
  - A categorical hot-spot finding is not an “exemption” from conformity itself, just hot-spot modeling
- Only applies for conformity, not for NEPA CO modeling

What Projects are Subject to PM Hot-spot Analysis?

- Projects of Air Quality Concern are . . .
  i. New highway projects that have a significant number of diesel vehicles, or expanded highways with a significant increase in diesel vehicles;
  ii. Projects affecting intersections at LOS D, E, or F with a significant number of diesel vehicles, or those that will change to LOS D, E, or F because of increased traffic volume from a significant number of diesel vehicles related to the project;
  iii. New bus and rail terminals and transfer points that have a significant number of diesel vehicles congregating at a single location;

40 CFR §93.123(b)(1)
What Projects are Subject to PM Hot-spot Analysis?

- Projects of Air Quality Concern are . . .
  - iv. Expanded bus and rail terminals and transfer points that significantly increase the number of diesel vehicles congregating at a single location; and
  - v. Projects in or affecting locations, areas, or categories of sites which are identified in the PM10 or PM2.5 applicable implementation plan or implementation plan submission as appropriate, as sites of violation or possible violation

More Resources for Conformity

- FHWA conformity web site:
- Regulations and guidance
- On-demand training
- Examples of conformity practices
- Nonattainment area maps
- Conformity Highlights newsletter
Mobile Source Air Toxics (MSATs)

- The 1990 Clean Air Act Amendments mandates EPA to regulate 188 hazardous air pollutants (HAPs)
- In 2001 and 2007 rulemakings, EPA identified a subset of these that come from mobile sources (MSATs)
- 7 MSATs account for most of the adverse health effects:
  - Benzene
  - Naphthalene
  - 1,3-Butadiene
  - Formaldehyde
  - Diesel Particulate Matter
  - Acrolein
  - Polycyclic Organic Matter
Health Impacts of MSATs

- While the science is evolving, regulatory agencies are concerned about MSAT exposure
- The 7 major MSATs are known or suspected carcinogens, and can have other adverse health impacts as well
- Benzene (a known carcinogen) and diesel particulate matter are viewed as especially harmful
- No NAAQS for MSATs, but advisory standards for some pollutants exist

MSAT Interim Guidance Update (2012)

MSAT Interim Guidance Update (2012)

- Guidance update to address MOVES and newer research
  - Diesel Particulate Matter dominates when MSATs modeled with MOVES
    - was benzene under MOBILE6.2
  - Research updates
  - Updates to Appendix C
    - language addressing CEQ Regulation 1502.22

FHWA MSAT Guidance Approach

- FHWA has developed a tiered approach for analyzing MSAT emissions in NEPA documents:
  - No analysis for projects with no potential for meaningful MSAT effects;
  - Qualitative analysis for projects with low potential MSAT effects; or
  - Quantitative analysis to differentiate alternatives for projects with higher potential MSAT effects
Exempt Projects

- No analysis is necessary
- Document in the project record that the project does not need an MSAT analysis because it qualifies as:
  - A categorical exclusion under 23 CFR §771.117(c);
  - Exempt from conformity under 40 CFR §93.126; or
  - Will have no meaningful impacts on traffic volumes or vehicle mix
- Prototype language provided in Appendix A of the Guidance

Screening Thresholds for Quantitative Analysis

- Quantitative emissions analysis is recommended for projects that
  1) Involve new or additional capacity on roadways where the traffic volume will be 140,000-150,000 AADT (or higher) in the design year, or
  2) Create or significantly alter an intermodal freight facility that generates high levels of diesel particulate emissions in a single location
- AND
  - are in proximity to populated areas, or in rural areas, in proximity to vulnerable populations (near schools, nursing homes, hospitals)
Qualitative Analysis for Projects with Low Potential MSAT Effects

- The NEPA document should include a qualitative discussion of project-specific factors that could affect MSAT emissions and exposure.
- Example language for different types of projects is included in Appendix B of guidance;
  - This language needs to be tailored to account for the unique characteristics and impacts of each project.

Quantitative Analysis for Projects with Higher Potential MSAT Impacts

- Emissions analysis at the study area/corridor level using MOVES.
- Analyze emissions of the 7 priority MSATs for base year (current conditions) and future no-action and build alternatives.
- RC and HQ staff can provide technical guidance on project-specific methodologies.
Quantitative Analysis for Projects with Higher Potential MSAT Impacts

- FHWA is developing FAQ’s on quantitative MSAT analysis with MOVES, including:
  - How to set up MOVES runs
  - Necessary types and sources of input data
  - Working with MOVES output
  - Troubleshooting and data management tips
- The MSAT session in this course covers the same topics

Predicted Changes in MSAT Emissions: Example
Mitigation

• If meaningful differences in emissions identified between alternatives, evaluate and consider mitigation

• Possible mitigation options:
  – Cleaner (newer) construction equipment
  – Retrofit of construction equipment/cleaner fuels
  – Alternative fuels (propane, biodiesel)
  – School bus retrofit
  – Truck stop electrification
  – Anti-idling ordinances

CEQ Regulation 1502.22: Incomplete or Unavailable Information

• Covers situations where an agency’s ability to evaluate reasonably foreseeable significant adverse impacts is affected by incomplete or unavailable information

• Air toxics is an emerging field, and many necessary tools and data are missing or incomplete
  – In cases like this, 1502.22 requires:
    • statement that information is incomplete or unavailable
    • statement of the relevance of the information
    • summary of existing credible scientific information
    • our evaluation of impacts
CEQ Regulation 1502.22: Incomplete or Unavailable Information

- Template language is provided for this discussion in Appendix C of the FHWA guidance
  - Needs to be tailored for each project

National MSAT Emission Trends for Vehicles Operating on Roadways

MOVES2010b
- - - VMT
- Total MSAT
- Diesel PM
- Benzene
- Formaldehyde
- Butadiene
- Naphthalene
- Acrolein
- Polycyclics
Other Issues Raised in NEPA

- Health Risk Assessment/Health Impact Assessment/Children’s Health
- Climate Change/Greenhouse Gas Emissions

Air Quality Health Issues Raised in NEPA

- As part of comments on NEPA documents, FHWA often receives requests for analysis that go beyond our guidance. These include:
  - Health Risk Assessment
  - Health Impact Assessment
  - Children’s Health Assessment
Air Quality Health Issues Raised in NEPA

• FHWA has not conducted more advanced forms of air quality health risk assessment for several reasons:
  1) Research available to FHWA suggests low health risk from MSATs
     • Project-specific MSAT risk assessments, NCHRP research studies, and EPA rulemaking support documents have all identified risks well below EPA's 100-in-a-million action level, and closer to EPA’s 1-in-a-million “negligible” level
     • Health risk from MSATs is hundreds of times lower than health risk from injury or fatality traffic accidents

Air Quality Health Issues Raised in NEPA

2) Health risk is declining regardless of FHWA decisions on project alternatives
   • EPA’s fuel and vehicle emissions control programs are producing reductions in emissions (and health risk) that are far larger than project impacts (emissions decline regardless of which alternative is selected)
3) Congestion relief projects can provide reductions in MSAT health risk for motorists
   • Higher speeds reduce MSAT emissions rates
   • Higher speeds also reduce the amount of time motorists are on roadways in traffic, where MSAT concentrations are the highest
Air Quality Health Issues Raised in NEPA

4) MSAT emissions analysis under FHWA's guidance provides tangible information on likely health impacts, without uncertainty of risk-based approaches
   • Limitations on toxicity information and assumptions made in risk-based assessments result in uncertainties spanning two orders of magnitude or more, far larger than the traffic and emissions changes associated with projects

5) FHWA NEPA documents also address the NAAQS, which are required by law to protect public health with an adequate margin of safety; if analyses demonstrate no violations of the NAAQS, health impacts would not be expected from those pollutants

Air Quality Health Issues Raised in NEPA

6) CEQ regulations regarding the content of NEPA documents suggests that risk assessments are not appropriate for NEPA
   • “High quality information, accurate scientific analysis”: MSAT HRA approaches involve large assumptions and uncertainties that overwhelm the influence of projects
   • “Concentrate on issues significant to the action in question, avoid amassing needless detail”: MSAT emissions (and health risk) are declining regardless of which alternative is chosen
   • “Documents should be analytic rather than encyclopedic, no longer than absolutely necessary”: MSAT emissions analysis provides adequate information for the public and decision-maker to see which alternative is “better” from an MSAT standpoint, without relying on more involved but more uncertain analysis approaches
Climate Change in NEPA

- Multiple aspects:
  1) Impact of the project on climate (greenhouse gas emissions impacts of the proposed project)
  2) Impact of climate change on the proposed project
     a) Direct impacts of future climate on infrastructure
     b) Cumulative effects of the project and future climate on the affected environment

GHG Emissions Analysis in NEPA: Current State of Affairs

- CEQ issued draft guidance (twice), never finalized
- FHWA does not have formal guidance
- Some states have state-level guidance
- Some EPA Regions have coordinated with FHWA Divisions on methods
- Case-by-case on projects in other areas
No FHWA Requirement for a GHG Emissions Analysis

- No national standards
- No EPA thresholds
- Climate impacts are global, not measurable
- Focus on issues that are significant and meaningful for decision-making
- Best addressed at the planning and programmatic level

Draft CEQ Climate Change in NEPA Guidance

- Issued February 18, 2010, reissued December 24, 2014
- Recommends that federal agencies address GHG emissions impacts of proposed actions where the analysis would “provide meaningful information to decision-makers”
- Recommends consideration of potential impacts of future climate change on proposed actions
- No set timeframe for final guidance
Draft CEQ Guidance: Greenhouse Gas Analysis

- Analyze GHG emissions if agency has determined that an analysis is appropriate
- Quantify direct, indirect, and cumulative emissions over life of the project
- Use interagency consultation to determine best procedures for evaluation
- Programmatic approaches may be accommodated (FHWA’s preference)

Draft CEQ Guidance: When to Analyze GHG Emissions

- EA and EIS with direct emissions of 25,000 metric tons per year
- Roughly a VMT increase of 190,000 miles per day
  – Based on 2035 GHG running emissions rates, not including construction emissions
- Direct emissions would probably also include construction and tailpipe emissions
When has CC been addressed in NEPA?

- When the state or local jurisdiction has a requirement
- When you’ve worked something out with your EPA Region
- When there is strong interest identified in scoping and/or comments

What Might I Include?

- Documentation of a state required analysis
- Reference to an analysis done at the planning level and/or
- Qualitative analysis and discussion
Example Framework for GHG Qualitative Analysis and Discussion

- Note that climate change is an important concern
- Include description of why GHGs from project aren’t significant
- Table showing statewide and project emissions potential compared to global totals

<table>
<thead>
<tr>
<th>Analysis Year</th>
<th>Global CO₂ Emissions (MMT)</th>
<th>State-wide Motor Vehicle CO₂ Emissions (MMT) (% of Global)</th>
<th>Project Area VMT (% of State-wide VMT)</th>
<th>Percent change in State-wide VMT due to Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Conditions (2012)</td>
<td>29,670</td>
<td>29.3</td>
<td>19.0%</td>
<td>(None)</td>
</tr>
<tr>
<td>Future Projection (2037)</td>
<td>42,380</td>
<td>37.4</td>
<td>18.6%</td>
<td>0.876%</td>
</tr>
</tbody>
</table>

Description of expected GHG emissions direction as a result of implementing the project, such as:
- Federal actions to reduce transportation GHG emissions including NHTSA fuel economy/GHG emissions standards
- State/local actions to reduce transportation GHG emissions
- Project elements to reduce GHG emissions
Climate Change Impacts/Adaptation: National Policy

- DOT Sustainability Strategic Plan (not specific to NEPA), developed pursuant to EO 13514
- DOT Policy Statement on Climate Change Adaptation:  
- EO 13653, “Preparing the United States for the Impacts of Climate Change”
- No FHWA NEPA guidance or requirements at this time

Why Consider Climate Change Effects During Project Development?

- **Direct impacts** on transportation infrastructure
- **Cumulative impacts** of transportation projects on an environment vulnerable to the effects of climate change
Climate Change Effects in Project Development

Regional Environment
Examples of elements of the built and natural environment that are potentially affected by climate change include:
- Towns or Cities
- Transportation Infrastructure
- Species Habitat and Biodiversity
- Water Supply and Water Quality
- Air Quality

1: Direct impacts of climate change on transportation infrastructure
2: Impacts of climate change on the natural and built environment
3: Cumulative impacts of the project and climate change on the environment

Resources: GHG Analysis

- FHWA HQ and Resource Center staff can provide assistance with GHG emissions analysis
- GHG analysis in both planning and NEPA:
  - SHRP2-C09 “Practitioners Handbook” available at www.trb.org/Main/Blurbs/166940.aspx
- Tailpipe emissions:
  - MOVES can be used (EPA has issued guidance, and FHWA can also provide lookup tables of emissions rates)
Resources: GHG Analysis

- Construction emissions:

Resources: Vulnerability Assessment/Adaptation

- FHWA HQ staff can provide assistance with climate vulnerability and adaptation considerations
- NCHRP Report 750, Volume 2: Climate Change, Extreme Weather Events, and the Highway System: Chapter 6 addresses project development
  - www.trb.org/Publications/PubsNCHRPProjectReports.aspx
- FHWA Vulnerability Assessment Framework, NEPA Adaptation Case Studies
  - www.fhwa.dot.gov/environment/climate_change/adaptation/
Documenting NEPA Air Analysis

Information that is Needed in the Text of the Document

- Affected environment (emphasis on “affected”)
- Summary of the results of the AQ analyses
- Project-level conformity documentation (if applicable)
- MSAT 1502.22 language on incomplete or unavailable information
  - Appendix C of MSAT guidance
- Language on climate change and GHG emissions
  - if requested by reviewing attorney
Information that Should be in an Air Quality Technical Report

- More detailed background information (if desired)
- Summary of traffic data used in analyses
  - VMT and speed by alternative
- Detail on emissions and/or dispersion modeling analyses
  - put tables of results here, not in the text of the document
- Full documentation of project-level analyses conducted for NEPA and hot-spot analyses conducted for conformity

Electronically-Available Information

- MOVES input and output files
- Emissions calculation spreadsheets
- Dispersion model input and output files
Session 2: Using MOVES for Quantitative MSAT Analyses

Session Outline

• Introduction to using MOVES at the County scale for quantitative project-level MSAT analysis
• Developing a County scale MOVES RunSpec
  – Building a county-scale MOVES RunSpec to produce an emissions inventory, including recommendations for each panel
• Entering data using the County Data Manager (CDM)
  – What is the CDM and how does it work?
  – Description/recommendations for each table in the MOVES input database
• Running MOVES (Executing the RunSpec)
  – Class exercise: Run MOVES for the MSAT inventory scenario
Important Disclaimer

- This session describes use of MOVES for NEPA MSAT analysis, NOT how to use MOVES for regional or project-level conformity analysis!
- For conformity applications of MOVES, refer to the applicable guidance and training materials on EPA’s MOVES web site

General Approach for Using MOVES for NEPA Air Quality Analysis
1) Start with a Plan

- What type(s) of analysis do I need for my NEPA document (emission inventory, hotspot for conformity, or both)?
- What pollutants am I modeling?
- What years and seasons am I modeling?
- What inputs do I need?
- What inputs vary by year? By season? By time of day? By alternative (No Action and Build)?
- What traffic and other data do I need to develop the inputs?

2) Get organized

<table>
<thead>
<tr>
<th>Framework for Hwy XX emissions analysis</th>
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<tbody>
<tr>
<td>Pollutants:</td>
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<tr>
<td>MSATs (the 7 listed in guidance)</td>
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<tr>
<td>GHGs (CO2, CH4, N2O)</td>
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<tr>
<td>Analysis years:</td>
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<tr>
<td>2015 base year, 2018 first year of operation, 2038 design year for No Action and Build alternatives</td>
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<tr>
<td>Seasons:</td>
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<tr>
<td>All 12 months</td>
</tr>
</tbody>
</table>

Note: This is just an illustrative example; for a real project, these parameters are decided, in part, through discussions with the project team.
2) Get organized

<table>
<thead>
<tr>
<th>Input*</th>
<th>Aspect</th>
<th>Source</th>
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</thead>
<tbody>
<tr>
<td>Age distribution</td>
<td>Same for all runs</td>
<td>MPO</td>
</tr>
<tr>
<td>Meteorology</td>
<td>Same for all runs</td>
<td>State Air Agency</td>
</tr>
<tr>
<td>I/M, fuels</td>
<td>Same for all alternatives, differ by year, fuels vary by season</td>
<td>State Air Agency</td>
</tr>
<tr>
<td>VMT, speed, road type distribution, ramp fraction</td>
<td>Unique for each run</td>
<td>Project traffic modeling</td>
</tr>
<tr>
<td>Day and month VMT fractions</td>
<td>Same for all runs</td>
<td>State DOT</td>
</tr>
<tr>
<td>Hour VMT fractions</td>
<td>Same for all runs</td>
<td>MPO</td>
</tr>
</tbody>
</table>

*Inputs explained in detail later

3) Develop master checklist of inputs for each run

<table>
<thead>
<tr>
<th>2018-NoAction-Winter emissions analysis run</th>
<th>Spreadsheet file</th>
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</thead>
<tbody>
<tr>
<td>Age distribution</td>
<td>Age_allruns.xls</td>
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<tr>
<td>Meteorology</td>
<td>Met_fullyear_allruns.xls</td>
</tr>
<tr>
<td>I/M</td>
<td>IM_2018.xls</td>
</tr>
<tr>
<td>Fuel supply</td>
<td>Fuel_2018_winter.xls</td>
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<tr>
<td>VMT</td>
<td>VMT_2018_NoAction.xls</td>
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<tr>
<td>Speed</td>
<td>Speed_2018_NoAction.xls</td>
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<tr>
<td>Road type distribution</td>
<td>Roadtypedist_2018_NA.xls</td>
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<tr>
<td>Ramp fraction</td>
<td>Ramps_2018_NA.xls</td>
</tr>
<tr>
<td>Month VMT fractions</td>
<td>MonthVMT_allruns.xls</td>
</tr>
<tr>
<td>Day VMT fractions</td>
<td>DayVMT_allruns.xls</td>
</tr>
<tr>
<td>Hour VMT fractions</td>
<td>HourVMT_2018.xls</td>
</tr>
</tbody>
</table>
4) Check with the project team and get feedback on the approach

- Does it address the concepts that were discussed in the original project team meeting?
- Will it satisfy applicable requirements for NEPA and MSAT analysis?
- Do the proposed MOVES inputs adequately characterize the effects of the project alternatives on travel?
- It’s always better to answer these questions before a lot of MOVES work is completed, instead of redoing work later
- Can also use this opportunity to request and define necessary input data from project team members

5) Develop and QA input spreadsheets

- Develop a set of spreadsheet inputs for one MOVES run
- Create the necessary RunSpec, and import the inputs using the County Data Manager for emissions analysis
  - Label run as a Test run to avoid later confusion
- Find and resolve any error messages from the CDM
- Execute the RunSpec and QA the output
- For this run, specify extra detail in Output Emissions Detail
  - getting output by process, sourcetype, fueltype, roadtype can help in troubleshooting problems
5) Develop and QA input spreadsheets

- Are all pollutants, processes, road types, etc. that you requested in the RunSpec included in the output?
  - Get “0” for any emissions?
  - Distance outputs agree with VMT inputs?
- If everything looks OK, then develop the spreadsheet inputs for the remainder of the runs

5) Develop and QA input spreadsheets

- Reality check on spreadsheets and raw data:
  - Related spreadsheets should each have the same number of rows and file size
  - Check that distributions that should sum to one, do sum to one
  - Does VMT really triple between No Action and Build
  - Is Build lower than No Action even though you’re adding lanes?
  - Is 30% of traffic really moving at 2.5 mph?
  - Do we really have motorcycle VMT in the winter, or twice as much truck VMT as car VMT?
6) QA and interpret output

- Check file size and # of rows in output—related runs should have the same size output
- Check for and investigate cases where emissions = 0
- Emissions trends make sense? Any obvious outliers?
- Can you explain why emissions between alternatives are different?
  - You’ll probably be asked, especially if the build alternatives are much lower than No Action

Working with output

- Test runs should have a lot of detail for troubleshooting
- Actual runs should distinguish emissions by road type; additional detail may be useful for troubleshooting or interpreting results, but add to the size of output:
  - Emissions Process—increases output by a factor of 2+
  - Sourcetype—factor of 13
  - Fueltype—factor of 2 or 3
  - Model year—factor of 31
- Can use Summary Reporter to condense detailed output, or use MySQL Query Browser and export to Excel
Use the latest version of MOVES

- Update to the newest version posted on EPA’s web site before starting the analysis
- Usually, RunSpecs and input databases prepared with older versions of the model are not fully compatible with the latest version
- Reviewing agencies will have the newest version installed, and may not be able to check your work or provide troubleshooting assistance if your runs are based on an older version

MOVES Updates/Grace Period

- When EPA releases a major revision to MOVES, a grace period is typically established
  - Grace period for MOVES2014 transition is two years
  - Analyses started with a previous version of MOVES (MOVES2010/a/b) can be completed with that version, within certain constraints
- If you plan to complete an ongoing analysis with an older version of MOVES, ensure that reviewing agencies are aware of this and maintain capability to conduct reviews and provide assistance based on the older version
Using MOVES at the County Scale: Introduction

- “County scale” does not refer to a geographic scale, but a method of operating MOVES
  - “National” scale—MOVES uses national default input data
  - “Project” scale—MOVES requires link-level input data
- Area-specific data must be entered when the County scale is selected
- Local data should be used for most inputs; access to default data is limited at the County scale
- Data can be exported or imported with the County Data Manager (CDM)

MOVES Technical Guidance

- Key source of guidance on use of local inputs and defaults
- Some input advice is presented in this course, but refer to Technical Guidance for more detail
- Posted on EPA’s MOVES web site: [www.epa.gov/otaq/models/moves/index.htm](http://www.epa.gov/otaq/models/moves/index.htm)
- Section 2.3.3 of the MOVES User Guide is a basic reference for use of the County Data Manager
Building a County-scale Inventory RunSpec

MOVES Structure: RunSpec

- MOVES Execution Database
- MOVES Master (MOVES GUI)
- Run Specification (RunSpec)
- Input Database
- Output Database
- Processed Output

User input
MOVES output
Other MOVES functions
Exercise Objectives

- Hands-on practice building a RunSpec and entering data for a county-scale MSAT emissions inventory run
- Exercise scenario is intentionally simplified to facilitate learning, limit complexity, and reduce MOVES run time
  - Pollutants, timeframes and vehicle types are limited compared to a real-world MSAT analysis
  - Should not be used as a complete template for a County scale run using MOVES for MSAT analysis

Scenario Description

- Modeling one county: Cobb County, Georgia
- Typical day in 2035
  - Will select month of July and model only “weekday” days, all hours to represent this typical day
  - Normally, the entire year would be covered by the modeling
- Subset of vehicle types
  - Diesel fuel and gasoline passenger cars and passenger trucks
  - Diesel fuel combination long-haul trucks
  - Normally, all vehicle types would be selected
Scenario Description (cont’d)

- All road types
  - Urban restricted and unrestricted
  - Rural restricted and unrestricted

- Benzene
  - Running Exhaust and Crankcase Running Exhaust
  - One MSAT (benzene) plus the required pollutant chains (VOC, NMH, THC) selected for training purposes
  - More pollutants would need to be modeled for a quantitative MSAT analysis

Starting MOVES: File, New RunSpec
Developing a RunSpec: County-scale Specifics

- Set up the entire RunSpec file first before the county inputs are added
  - This enables the County Data Manager (CDM) to filter the default database for relevant information
  - CDM also conducts error-checks on imported data based on selections made in the RunSpec
  - Output database must be identified to store the results

- The RunSpec can only have
  - A single county (or custom domain) selected
  - A single calendar year selected

Developing a RunSpec: County-scale Specifics

- A County input database with local inputs must be provided
  - Can be created/populated with CDM – more later
The Description Panel allows the user to detail what the RunSpec being constructed will model:

- Up to 5,000 characters of text, but no quote, ampersand or backslash characters allowed.

IMPORTANT: Use the Description panel to describe the scenario being modeled, so you know later what that run represents!!

- The Description entered will appear in the MOVESRun table of the output database.

Instructions: Type “Cobb County – MSAT Training RunSpec”
MOVES2014 can model both Onroad and Nonroad sources; FHWA MSAT analyses include only Onroad emissions.

- County scale must be used for SIPs or transportation conformity analyses; FHWA recommends it for MSAT analysis.
  - National scale relies on national defaults and allocation factors that are not appropriate for regulatory purposes, and may not be valid for the project.
  - National scale can be used for GHG analysis.
- Instructions: Select Onroad, County.

Either Inventory or Emission Rates options may be used for MSAT analyses.

- Pros and cons of Rates approach discussed later in this course.
- Best to use the same approach when comparing two or more cases.
  - Base year and design year.
  - Different project alternatives.
- Instructions: Select Inventory.
Scale Panel

Make the following selections for our exercise

- Time Aggregation Level should be set to Hour
- All months, days, hours should be selected
  - As an option, can model 4 months to represent the seasons, instead of all 12; still need all days and hours
  - Will require post-processing to get annual emissions
- Only one calendar year can be selected per run
  - Baseline/existing year
  - Design year
  - First year of operation (recommended)

Time Spans Panel

- MSAT analyses need to reflect long-term exposure
- Selections:
  - Time Aggregation Level should be set to Hour
  - All months, days, hours should be selected
    - As an option, can model 4 months to represent the seasons, instead of all 12; still need all days and hours
    - Will require post-processing to get annual emissions
  - Only one calendar year can be selected per run
    - Baseline/existing year
    - Design year
    - First year of operation (recommended)
Time Spans Panel

Make the following selections for our exercise

- Select the county where the project is located
  - If the project spans more than one county, choose the most representative one, or construct a Custom Domain
- Choosing a county allows access to the available default data stored for that county
- The Enter/Edit Data button in the Domain Input Database portion of the panel opens the County Data Manager
  - A County database must be created or selected to store the county specific data (done later)
- Will show after County database has been provided

Geographic Bounds Panel

- Select the county where the project is located
  - If the project spans more than one county, choose the most representative one, or construct a Custom Domain
- Choosing a county allows access to the available default data stored for that county
- The Enter/Edit Data button in the Domain Input Database portion of the panel opens the County Data Manager
  - A County database must be created or selected to store the county specific data (done later)
- Will show after County database has been provided
Geographic Bounds Panel

On Road Vehicle Equipment Panel

- Select all valid fuel/vehicle type combinations
  - Invalid combinations include: diesel motorcycle, gasoline long-haul combination truck, gasoline intercity bus, and numerous CNG, electricity, and LPG vehicle combinations
  - Both Gasoline and E-85 should be selected when modeling gasoline vehicles
  - If using MOVES2010b and earlier, don’t select “placeholder” fuel type — can cause errors
For our class exercise, we will only model a subset of vehicle/fuel combinations to keep model runtime short:
- Diesel Fuel/Combination Long-Haul Truck, Passenger Car, Passenger Truck
- Gasoline/Passenger Car, Passenger Truck
- E-85/Passenger Car, Passenger Truck

By default, MOVES assigns some VMT to Compressed Natural Gas (CNG) (for transit buses) and E85 (passenger cars and passenger trucks)
- Therefore, users should either select the CNG transit bus vehicle combination, and E85 passenger car and passenger truck; or
- Edit the Fuel inputs in the CDM so that no VMT is allocated to CNG and E85 for the affected vehicle types
- If one of these approaches is not used, some VMT assigned to these vehicle types will be “lost” (disregarded by MOVES)
- We will cover this more when discussing the CDM.
Make the following selections for our exercise

- Select all road types in the affected network
  - RoadTypeDistribution table in CDM is used to allocate VMT to the various road types
- Don’t select “off-network” road type
  - Captures start, extended idle, and resting evaporative emissions; these emissions aren’t included in NEPA MSAT analysis
- Notes on ramps:
  - “Provide separate ramp output” check box instructs MOVES to report ramp and mainline emissions inventory separately for restricted access road types (not needed for our exercise)
  - A restricted road type must be selected for the Ramp Fraction tab to appear in the CDM
Make the following selections for our exercise:

**Road Type Panel**

- Diesel-fueled Vehicles
  - Pollutants
    - Primary Exhaust PM10 – Total
  - Pollutant Chains
    - Primary PM10 – Organic Carbon
    - Primary PM10 – Elemental Carbon
    - Primary PM10 – Sulfate Particulate
    - Total Energy Consumption
  - Processes
    - Running Exhaust and Crankcase Running Exhaust

**Pollutants and Processes Panel**

- Diesel-fueled Vehicles
  - Pollutants
  - Pollutant Chains
  - Processes
Pollutants and Processes Panel

- All Selected Fuel/Type Combos
  - Pollutants
    - Benzene
    - 1,3-Butadiene
    - Formaldehyde
    - Acrolein
    - Polycyclic Aromatic Hydrocarbons
      - (Naphthalene and Polycyclic Organic Matter)
  - Pollutant Chains
    - Volatile Organic Compounds
    - Non-Methane Hydrocarbons
    - Total Gaseous Hydrocarbons
    - Primary PM2.5 - Organic Carbon

Pollutants and Processes Panel

- All Selected Fuel/Type Combos
  - Processes
    - Running Exhaust and Crankcase Running Exhaust
    - Evap Permeation and Evap Fuel Leaks
### Polycyclic Organic Matter

<table>
<thead>
<tr>
<th>Compound</th>
<th>Form</th>
<th>pollutantID</th>
<th>Form</th>
<th>pollutantID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dibenzo(a,h)anthracene</td>
<td>particle</td>
<td>68</td>
<td>gas</td>
<td>168</td>
</tr>
<tr>
<td>Fluoranthene</td>
<td>particle</td>
<td>69</td>
<td>gas</td>
<td>169</td>
</tr>
<tr>
<td>Acenaphthene</td>
<td>particle</td>
<td>70</td>
<td>gas</td>
<td>170</td>
</tr>
<tr>
<td>Acenaphthylene</td>
<td>particle</td>
<td>71</td>
<td>gas</td>
<td>171</td>
</tr>
<tr>
<td>Anthracene</td>
<td>particle</td>
<td>72</td>
<td>gas</td>
<td>172</td>
</tr>
<tr>
<td>Benz(a)anthracene</td>
<td>particle</td>
<td>73</td>
<td>gas</td>
<td>173</td>
</tr>
<tr>
<td>Benzo(a)pyrene</td>
<td>particle</td>
<td>74</td>
<td>gas</td>
<td>174</td>
</tr>
<tr>
<td>Benzo(b)fluoranthene</td>
<td>particle</td>
<td>75</td>
<td>gas</td>
<td>175</td>
</tr>
<tr>
<td>Benzo(g,h,i)perylene</td>
<td>particle</td>
<td>76</td>
<td>gas</td>
<td>176</td>
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<tr>
<td>Benzo(k)fluoranthene</td>
<td>particle</td>
<td>77</td>
<td>gas</td>
<td>177</td>
</tr>
<tr>
<td>Chrysene</td>
<td>particle</td>
<td>78</td>
<td>gas</td>
<td>178</td>
</tr>
<tr>
<td>Fluorene</td>
<td>particle</td>
<td>81</td>
<td>gas</td>
<td>181</td>
</tr>
<tr>
<td>Indeno(1,2,3,c,d)pyrene</td>
<td>particle</td>
<td>82</td>
<td>gas</td>
<td>182</td>
</tr>
<tr>
<td>Phenanthrene</td>
<td>particle</td>
<td>83</td>
<td>gas</td>
<td>183</td>
</tr>
<tr>
<td>Pyrene</td>
<td>particle</td>
<td>84</td>
<td>gas</td>
<td>184</td>
</tr>
</tbody>
</table>

Select Running Exhaust; Evap Permeation; Evap Fuel Leaks; and Crankcase Running Exhaust processes for our exercise.

Can make Processes selections, then “Select Prerequisites” to automatically pick the additional Pollutants required.
Select Running Exhaust; Evap Permeation; Evap Fuel Leaks; and Crankcase Running Exhaust processes for our exercise.

Scroll to see additional Processes
Note that Prerequisites not auto-selected for Crankcase Running Exhaust; not needed for benzene calculations (i.e., not an error).

No entries for our exercise
Rate of Progress Panel

No entries for our exercise

User must identify the output database

- Best practice is to name output databases ending with "_out"
- Manually create the database if it doesn’t already exist
- Multiple RunSpecs can be stored in the same database
  - Will be identified by different MOVESrunID’s
  - Generally, there should be a reason to have multiple RunSpecs in the same output database (e.g., each run is a different alternative for the same year)

Units must be selected; “grams” recommended for MSATs if results will be reported in mass/day; otherwise “pounds” or “tons” OK
General Output Panel

- Activity output selections are optional
  - Selecting “Distance Traveled” is recommended for QA checks
Aggregation of the Time level: “Year” minimizes post-processing
  – Only valid if all months, days, hours selected in Time Spans panel

Location: County

Fuel Type: yes
  – needed to calculate DPM, which is only from diesel vehicles

Road Type, Source Use Type: only if you want output in that much detail
  – will need to sum outside of MOVES for presentation in NEPA document
SCC, Regulatory Class, Model Year, Emissions Process: never

As noted earlier, might want to select more detail for test runs to assist in troubleshooting, e.g.,

– if “source use type” is selected, output will be by vehicle type
– if emissions results are zero for some vehicle types, this helps you determine where to look for erroneous inputs
– Source Use Type, Road Type, and Month can also be useful for this purpose (don’t need to select them all at once)
We’ve completed our RunSpec selections for this run. We want to save this before proceeding with the County Data Manager.

Instructions: Save as “cobb_2035_msat.mrs” in the “CDM Input Files” folder supplied.
Saving the RunSpec

Using the MOVES County Data Manager (CDM) for MSAT Analysis
What is the County Data Manager?

- The County Data Manager (CDM) is a tool that facilitates the process of entering data into a county input database
  - The data in the input database is used by MOVES when executing the run
- CDM takes the form of a separate Graphical User Interface (GUI) that is used in conjunction with the MOVES Master GUI
  - When the CDM is open, the MOVES Master GUI is frozen and no changes can be made to the RunSpec
What is the County Data Manager?

- Data is not entered directly in the CDM
  - Users manipulate data in Excel worksheets, then “Import” worksheet into the CDM

County Data Manager Functions

- The CDM can create templates, export default data (when available), or export previously imported data
  - The files created through the CDM provide the proper format of the input tables, which is important
- Users review CDM data for accuracy before conducting a MOVES run
  - At the County scale, MOVES process requires users to export and re-import default data so that users examine each input and the most up-to-date information can be used in modeling
More CDM Functions

- The CDM imports (enters) the data into the county input database
  - Add descriptions of data being imported
  - Descriptions are useful for documentation of data sources
- Imported data can be cleared for each tab or the entire database can be emptied
  - Should always clear previously-imported data before importing new data for the same input; prevents execution errors

Opening the County Data Manager

- Two ways to open the CDM:
  - “Enter/Edit Data” button on the Geographic Bounds panel; or
  - Use the “Pre Processing” pull-down menu
- If the input database you want to use already exists, it can be selected in the Domain Input Database drop-down list; otherwise, new input database can be created in CDM
Opening the County Data Manager

A Newly Opened CDM
Using the CDM: General Info

• and symbols for each tab are determined by the relationship between the selections made in the RunSpec and the data provided by the user
  – appears when the user has provided data that is sufficient and passes error checks for all parameters in the RunSpec; note that two tabs begin with a green check (Generic and Ramp Fraction)
  – appears if the user has not provided enough information or if there is an error with the data provided
  – Nothing done in the CDM will affect the selections in the RunSpec

Using the CDM: General Info

• “RunSpec Summary” tab restates selections made in the RunSpec
  – Helpful reference while using CDM – see next slide
• “Tools” tab (not covered in this course)
  – Used to automate data import process and for batch operation
Using the CDM:
RunSpec Summary Tab

Using the CDM:
Database Tab
Using the CDM: Database Tab

- County input database is selected or created here
- Existing county input databases can be selected from the drop-down menu
- Once a county input database has been created or selected, the tables within it can be edited with the other CDM tabs
  - All the tables in the database can be cleared of data with the “Clear All Imported Data” button
- The tab also displays a log of changes

Creating a New County Input Database

Best practice:
End input database names with "_in" to help identify them as input databases
Creating a New County Input Database

Using the CDM: Options for Entering Data

- Export default data (into Excel)
- Review/edit default data
- Import back into input database

Note how default data must also be exported, then imported!

- Yes: Does MOVES have default data for a tab?
- No: Create Excel template
- Populate template with local data
Using the CDM: Creating a Template

- All tabs provide the option of creating an Excel template spreadsheet of the appropriate MOVES table
  - Save as.xls extension to get a spreadsheet format
- Templates contain the proper fields/column headings, but have blank cells for user-specified data
- The template will be pre-populated with some data based on entries made in the RunSpec
  - This is why it’s recommended to complete all RunSpec panels first!
- Extra worksheets will help you decipher MOVES codes

Example: Creating a Template
Example: Creating a Template

- Example template of SourceTypeYear table created from the “Source Type Population” tab of the CDM
- Note that “YearID” and “SourceTypeID” have been pre-populated based on RunSpec selections; “SourceTypePopulation” fields will need to be filled in by the user

Using the CDM: Exporting Default Data

- Some tabs have default data available:
  - Average Speed Distribution
  - Ramp Fraction
  - Fuel
  - Meteorology Data
  - Vehicle Type VMT (Month, Day, and Hour VMT Fractions)
  - I/M Programs
- Tabs with default data will have “Export Default Data” option
Example: Exporting Default Data

Example of exported default data for FuelSupply table created from the “Fuel” tab of the CDM

Per MOVES Technical Guidance, user would check default data to ensure applicability and make any changes
Data must be imported back into the CDM from Excel for each tab (even when using default data for a tab)

Imported data is read from a Excel worksheet that has been properly formatted with the correct columns

Using the CDM: Importing Data

General steps:
1) Recommended: Add a description of the data you are about to import (e.g., the file location or data source)
2) Browse to find the correct Excel file
3) Select the Excel file
4) Select the appropriate worksheet (when using defaults, name should match Data Source in the CDM tab)
5) Click the “Import” button

Check to see if you get an “Import Complete” message
Using the CDM: Importing Data

- When the import is successfully completed the will change to a on the County Data Manager tab
  - If message says, “Import Complete” but remains, that means more data is required (e.g., data was not provided for all source types selected in the RunSpec)
  - For many tables, unused data can be imported (e.g., extra months, hours, source types, etc.) with no adverse impacts; however, data for additional counties and years should NOT be imported as this can cause errors when attempting to execute the RunSpec
- The description you entered will appear in the log, which can be viewed on the Database tab

Example: Importing Data
Example: Importing Data

Example: Importing Data

Database tab log shows FuelSupply has been imported (with date/time stamp)
We will go through each data input (MOVES table) that can be accessed through each CDM tab. We will look at the fields in each input table and go over FHWA’s recommendation for that input. After discussing each input, we will enter the appropriate data for our MSAT inventory exercise for Cobb County. Exercise files can be found in the “CDM Input Files” folder.
## What MOVES inputs are needed for MSAT analysis?

### Possible inputs for an MSAT analysis run

<table>
<thead>
<tr>
<th>Age distribution</th>
<th>Source type population</th>
<th>Meteorology</th>
<th>I/M</th>
<th>Fuel parameters</th>
<th>VMT</th>
<th>Speed</th>
<th>Road type distribution</th>
<th>Ramp fraction</th>
<th>Month VMT fractions</th>
<th>Day VMT fractions</th>
<th>Hour VMT fractions</th>
</tr>
</thead>
</table>

- **Need to consider:**
  - What inputs will change as a result of the project?
  - What inputs have local data available?

## Summary of Data Inputs

- **Meteorology tab**
  - Temperature and humidity inputs
  - MOVES table: ZoneMonthHour

- **Source Type Population tab**
  - Number (i.e., population) of local vehicles operating in the area
  - Important for start and evaporative emissions; these emissions are not used in MSAT analysis, but this input needed for MOVES to run
  - MOVES table: SourceTypeYear
Summary of Data Inputs

• Age Distribution tab
  – Age fractions of fleet by age and source type
  – MOVES table: SourceTypeAgeDistribution

• Vehicle Type VMT tab
  – Total annual VMT by HPMS vehicle type
  – Also month, day and hour VMT fractions
  – MOVES table: HPMSVTypeYear (and others)

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Summary of Data Inputs

• Average Speed Distribution tab
  – Speed distribution by road type, hour and source (vehicle) type
  – MOVES table: AvgSpeedDistribution

• Road Type Distribution tab
  – Fraction of source type VMT on different road types
  – MOVES table: RoadTypeDistribution

• Ramp Fraction tab
  – Fraction of freeway VHT occurring on ramps
  – MOVES table: RoadType

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Summary of Data Inputs

- **Fuel tab**
  - Market share and composition of fuel blends
  - Travel fraction by vehicle and fuel type
  - Defaults available by fuel sales region (groups of counties)
  - MOVES tables:
    - FuelSupply
    - FuelFormulation
    - FuelUsageFraction
    - AVFT (fuel type and technology inputs)

Summary of Data Inputs

- **I/M Programs tab**
  - Data on I/M program(s), if any
  - MOVES table: IMCoverage
- CDM has additional tabs for inputs not typically used in MSAT analysis
  - Retrofit
  - Hoteling
  - Starts
  - “Generic” (other possible inputs without a specific tab)
Some of the suggestions for input data in this course are different than those in MOVES courses oriented toward SIP and conformity analysis.

For MSAT (or GHG) analysis, we are comparing years and alternatives, not trying to calculate an exact number to compare to a target.

Inputs that would be affected by the project alternatives (e.g., speed) are important to get right; inputs that are not affected by alternatives (e.g., temperature) are not as important in MSAT analysis.
Meteorology Data

- Meteorology data should be entered for every month and hour selected in the RunSpec
- Temperatures are in degrees Fahrenheit
- Relative humidity must be between 0 and 100
- ZoneID is simply the countyID + a zero

Meteorology Data: FHWA Recommendation

- Section 4.2 of MOVES Technical Guidance
- If the area conducts annual PM2.5 analysis (e.g., they are a nonattainment area for this pollutant), local temperature and humidity data for all 12 months are probably available and should be used
- If local data are not available, MOVES default data can be used
Let’s enter meteorology data into the CDM for our MSAT inventory exercise

The template has already been filled out with our meteorological data and is available as file: cobb_2035_meteorology.xls

**Instructions:** Open cobb_2035_meteorology.xls, review the data, and import the table into the Meteorology tab.
Browse and import the cobb_2035_meteorology worksheet

MSAT Inventory Exercise: Entering Meteorology Data

Age Distribution

- Age Distribution is entered according to MOVES source types and calendar year
  - AgeFraction must sum to “1” within these fields
- Age Distribution covers new (0) to 30+ year old vehicles
- MOVES does not vary age distribution by month
- EPA has age distribution converters on web, if needed
Age Distribution:
FHWA Recommendation

- Section 4.4 of MOVES Technical Guidance
- Emissions are sensitive to age and age distributions vary considerably by locality, but not affected by projects
  - Possible exception: transit projects that include purchase of new buses
- Use local age distribution data if available
  - varies by year, so needed for base year, first year of operation, and design year
- Otherwise, use defaults downloaded from “tools” section of MOVES web site
  - but don’t use a mix of defaults and local data for different years

Age Distribution:
Exercise

- Let’s enter age distribution data into the CDM for our MSAT inventory exercise
- Instructions: The template has already been filled out with our local age distribution and is available as file – cobb_2035_age_distribution.xls
Contents of cobb_2035_age_distribution.xls

MSAT Inventory Exercise: Entering Age Distribution Data

Browse and import the cobb_2035_age_distribution spreadsheet
**Source Type Population**

Source Type Population is the actual number of vehicles of each “source type” (vehicle type) in the county being modeled.

---

**Source Type Population: FHWA Recommendation**

- Section 4.3 of MOVES Technical Guidance
- Start and evaporative emissions depend upon vehicle population
  - these emissions are not included in MSAT analysis, but population inputs still needed for MOVES to run
- Use local population data if available (needed for project analysis years); otherwise use defaults
Source Type Population: Obtaining Defaults

- Sources of default population data
  - Can run MOVES2010b at the National scale for each of the project analysis years and get default vehicle population in the output (this approach doesn’t work in MOVES2014)
    - Select off-network road type and all vehicle/fuel types in the area
    - Model start emissions for one pollutant (total energy works and is fastest)
    - Check “population” in General Output panel
  - MOVES2014: default national populations by year available in the sourcetypeyear table of the default database
    - Can allocate to counties by: 1) multiplying by the “startAllocFactor” fraction in the MOVES default zone table for your county, or 2) calculate the ratio of county VMT to national VMT, and use that ratio

Source Type Population: Exercise

- Let’s enter source type population data into the CDM for our MSAT inventory exercise
- Instructions: The template has already been filled out with our local source type population and is available as file –
  cobb_2035_source_type_population.xls
Browse and import the sourceTypeYear worksheet

MSAT Inventory Exercise: Entering Source Type Population Data

The Fuel tab contains four data tables:
- Fuel Supply
- Fuel Formulation
- Fuel Usage Fraction
- AVFT

Data must be selected/entered for each table

Changes from MOVES2010b:
- In MOVES2010b, the Fuel tab included only the first two tables were included, and AVFT data were entered under a separate tab (Fuel Type and Technologies)
- Fuel Usage Fraction is a new input in MOVES2014
Fuel: Fuel Supply Data

- Fuel Supply entered by county, year, month, fuel type
  - MarketShare (column E) should sum to 1 within these fields

Fuel: Fuel Formulation Data

- Use only existing FuelFormulationID’s with the proper FuelSubTypeID for the fuel properties being entered
  - However, properties can be changed for existing formulations
  - Gasoline FuelFormulationIDs are 500-9419; diesel 20011-20491
  - Consult MOVES Technical Guidance for information about the requirements for populating each field
New input in MOVES2014 to accommodate E-85
  – Fraction of E-85 capable (“flex-fuel”) vehicles actually operating on E-85

Users can allocate VMT fractions to engine or fuel technologies
  – If fraction of VMT is not known, fraction of population can be entered

Most common use is to change default diesel or CNG fractions

E-85 added in MOVES2014
  – Since these vehicles can operate on E-85 or conventional gasoline, Fuel Usage Fraction is used to account for actual fuel use; AVFT would be used to modify fraction of fleet capable of using E-85
FuelType and Technologies: CNG Transit Bus

- MOVES default assumption is that transit buses are a mix of diesel, gasoline, and CNG based on national sales data for each model year.
- However, local bus fleets are likely to be different (e.g., 100% diesel or 100% CNG).
  - If the VMT fraction is not changed, MOVES will allocate bus VMT using the default VMT fractions, even if only one fuel type is selected in the RunSpec.
    - MOVES will assign some VMT and emissions to diesel buses even if CNG buses only are selected in the RunSpec, unless the fuel type fraction is changed.

Fuel: FHWA Recommendation

- Section 4.9 of MOVES Technical Guidance.
- Use local data if available, otherwise use defaults.
  - Like other defaults, default data need to be exported from default database and imported into project run input database.
- Make sure CNG bus selection in RunSpec is consistent with data in FuelType and Technologies inputs.
- Input data may vary by year, should not vary by alternative.
Let's enter fuel data into the CDM for our MSAT inventory exercise

**Instructions:** Export the default fuel information MOVES has for Cobb County, check the values, then import into the Fuel tab.
Browse and import the FuelSupply worksheet

MSAT Inventory Exercise:
Entering Fuel Supply Data

Browse and import the FuelFormulation worksheet

MSAT Inventory Exercise:
Entering Fuel Formulation Data
MSAT Inventory Exercise: Entering Fuel Usage Fraction Data

Browse and import the FuelUsageFraction worksheet

MSAT Inventory Exercise: Entering AVFT Data

Browse and import the avft worksheet
MSAT Inventory Exercise: Importing Fuel Data

Only one I/M program can be applied to each pollutant-process, source type, fuel type, model year combination.

IMProgramID is arbitrary number but must be unique for each fuel type, inspection frequency, test standard combination.
**I/M Programs: FHWA Recommendation**

- Section 4.10 of MOVES Technical Guidance
- Use local input data, otherwise use defaults
  - Unique input data file needed for each analysis year; I/M program parameters may also vary by year
  - Should not vary by alternative

**I/M Programs: Exercise**

- Let’s enter our I/M data into the CDM for our MSAT inventory exercise
- **Instructions:** Export the default I/M data for Cobb County, and import the table into the I/M Programs tab
MSAT Inventory Exercise: Entering I/M Programs Data

Export default data – Save as cobb_2035_im.xls

- cobb_2035_im_defaults.xls as exported with default data
Browse and import the IMCoverage worksheet

Project-specific Traffic Data for MSAT Analysis
Project-Specific Input Data from an Affected Transportation Network

- Average Speed Distribution
- Vehicle Miles Travelled
  - Annual VMT by HPMS class
  - Month, Day, Hour VMT fractions
- Road Type Distribution
- Ramp Fraction

Average Speed Distribution

- Average Speed Distribution entered according to source type, road type, and hour-day
  - AvgSpeedFraction should sum to 1 within these fields
- MOVES has 16 speed bins ranging from 2.5 to 75+ mph
Average Speed Distribution

- Average Speed Distribution is in terms of time, not distance (i.e. fraction of VHT, not VMT, in each speed bin)
- Speeds can vary by road type, hour, and vehicle type
  - Most analyses do not account for different speeds by vehicle type, but this can be a factor in some cases (e.g., lower truck speed limits)
- AvgSpeedDistribution table can be very long (~40,000+ rows) if RunSpec covers all source types, road types, day types, and hours
  - Some automation (or a lot of patience) needed to produce these files

Average Speed Distribution: FHWA Recommendation

- Section 4.6 of MOVES Technical Guidance
- Local speed distribution data are needed, by year and alternative
  - Any project where the Purpose and Need includes congestion relief (almost all of them) needs speed inputs that vary by alternative
  - For temporal aspects, speed distribution data can be entered at the hourly level, but varying the speed distribution for peak and off-peak hours is also acceptable; however, daily average speeds will minimize the effects of congestion relief on the emissions calculations (see next slide)
Example: PM$_{2.5}$ Trends by Vehicle Speed

Average Speed Distribution: FHWA Recommendation

- MOVES has four road types which are affected by the speed distribution
  - Urban restricted and rural restricted road types are generally interstates and highways
  - Urban unrestricted and rural unrestricted road types are generally arterials, collectors, and local roads
- If separate speed distributions are known for arterials, collectors, and local roads, calculate a weighted speed distribution that applies to all urban or rural unrestricted roads
MPO travel demand forecasting (TDF) models typically produce link-level output that can be used to develop speed distributions, road type distributions and ramp fractions.

Output will need to be “mapped” to MOVES format:
- Map TDF model road types to MOVES road types
- Map TDF model time periods to MOVES hours
- If different vehicle types are modeled, map vehicle types to MOVES source types
- If different geographic areas modeled (e.g., CBD, urban, suburban, etc.), map to MOVES urban and rural groups.

Average Speed Distribution:
Working with Travel Model Data

- Type = link type (highway, transit, etc.)
- Area = area type (CBD, urban, suburban, etc.)
- Factype = roadway type (freeway, major arterial, etc.)
- AB_AM1VOL = traffic volume in the A to B direction during the first a.m. time period
  - BA_AM1VOL = traffic volume in the B to A direction
- AB_AM1SPD = traffic speed in the A to B direction during the first a.m. time period
  - BA_AM1SPD = traffic speed in the B to A direction
- This example continues for 9 more time periods and ~ 19,000 more links.
Average Speed Distribution: Steps in Developing Speed Inputs

- Map to the four relevant MOVES road types
  - No VMT or VHT on RoadTypeID = 1 (“off-network”)
  - Use only roadway links, not rail, bike, walk links
- Sort by speed bin
- Calculate VHT by speed bin and road type (link length times volume divided by speed = VHT)
  - If ramps coded separately, use only freeway mainline segments in VHT calculations, but still need to reflect ramp VMT in VMT inputs
- Sum total VHT by road type and then calculate bin fractions

Average Speed Distribution: Steps in Developing Speed Inputs

- Repeat for each time period; map to MOVES hours
- If multiple vehicle types modeled, repeat for each vehicle group and map to MOVES source type
  - Some areas do separate traffic assignment for cars, trucks, and other classes
  - If bus transit links modeled separately, calculate speeds separately and use these speeds for the transit bus source type)
- If multiple area types, then map to rural and urban
  - Can also handle as zones in MOVES2010b
Wildcards allow you to populate multiple rows of a database table with identical information—e.g., using the same speed for all vehicle types, or both weekdays and weekends—See page 66 of the MOVES2010b Users Guide.

Using Wildcards

- Wildcards allow you to populate multiple rows of a database table with identical information—e.g., using the same speed for all vehicle types, or both weekdays and weekends—See page 66 of the MOVES2010b Users Guide.

Another Option:
EPA’s “MOBILE6 Converter”

- “Average Speed Converter MOBILE6”, posted at www.epa.gov/otaq/models/moves/tools.htm
- Starting with project travel data, develop VMT (not VHT) fractions for the 14 MOBILE6 speed bins, and copy into the tool—Tool uses input format identical to the “SPEED VMT” inputs in MOBILE6—If rural and urban roads selected in RunSpec, both inputs needed.
Another Option: EPA’s “MOBILE6 Converter”

- Tool automatically creates a correctly formatted and fully populated MOVES input spreadsheet, with same speed distribution for all vehicle types and day types
- “Average Speed Converter MOBILE6”, posted at www.epa.gov/otaq/models/moves/tools.htm
- Starting with project travel data, develop VMT (not VHT) fractions for the 14 MOBILE6 speed bins, and copy into the tool
  - Input format identical to the “SPEED VMT” inputs in MOBILE6
  - If rural and urban roads selected in RunSpec, both inputs are needed

Average Speed Distribution: Exercise

- *Instructions*: Review cobb_2035_avg_speed_distribution.xls and import into the Average Speed Distribution tab
MSAT Inventory Exercise: Entering Average Speed Distribution Data

Contents of cobb_2035_avg_speed_distribution.xls

Browse and import the AvgSpeedDistribution Worksheet from cobb_2035_avg_speed_distribution.xls
MOVES requires annual VMT but also VMT fractions by month, day, and hour.
Annual VMT is entered for each HPMS vehicle class; others by MOVES source type.

- **Month VMT fractions**
  - Fraction of annual VMT (per source type) occurring per month.

- **Day VMT fractions**
  - Fraction of monthly VMT (per source type and road type) occurring on one of two day types (weekday or weekend).

- **Hour VMT fractions**
  - Fraction of daily VMT (per source type and road type and day type) occurring per hour.
VMT is entered for each HPMS vehicle class
- light-duty HPMS classes revised in MOVES2014: passenger cars and light trucks combined

VMT will vary by year and alternative

Vehicle Type VMT: Month VMT Fraction

- MonthVMTFraction must sum to 1 within each source type over a 12-month period
- In MOVES2010b, “isLeapYear” field (not shown here) must match year selected in the RunSpec for MOVES to run properly
  - e.g., “Y” if the RunSpec year is a leap year, “N” if not
Vehicle Type VMT: Day VMT Fraction

- DayVMTFraction must sum to 1 within each source type, month, road type combination
- DayVMTFraction is in terms of the fraction of VMT on each type of day throughout the entire month
  - i.e., ~22 weekdays and 9 weekend days in a 31 day month; 22/31 = 0.71, similar to default values

Vehicle Type VMT: Hour VMT Fraction

- HourVMTFraction must sum to 1 within each source type, road type, type of day combination
- HourVMTFraction is applied to all months
  - If data varies for different months, you will need to run different RunSpecs for each
Annual VMT and VMT Fractions: FHWA Recommendation

- Section 4.5 of MOVES Technical Guidance
- Year- and alternative-specific annual VMT data are required
  - Required for 5 HPMS vehicle classes (6 classes in MOVES2010)
  - Total VMT for the project alternatives can be allocated to HPMS classes using count data, or the relative fractions used in any regional emissions analysis
    - e.g., for SIP inventories or conformity
  - Can also get a default split by running MOVES at the National scale and selecting Distance in the output
    - group the related sourcetypes to get VMT by HPMS class

Annual VMT and VMT Fractions: FHWA Recommendation

- Local VMT month, day, and hour fractions should be used if data are available; otherwise, defaults are acceptable
- Troubleshooting suggestion: once you have annual VMT by HPMS class and the three different fractions (month/day/year), do a test run in MOVES to make sure that the combination of these inputs results in the correct daily VMT, and that the VMT by sourcetype looks reasonable
  - select “Distance” and “Source Use Type” in the output to see what VMT MOVES calculated based on your inputs
Annual VMT and VMT Fractions: FHWA Recommendation

- More advice: run this test before you do all the MOVES runs for your analysis!

MSAT Inventory Exercise: Entering Vehicle Type VMT Data

Total VMT and month, day, and hour VMT fractions are all imported from this tab.

You will have to browse/import 4 spreadsheets to complete this tab:
- cobb_2035_hpms_vtype.xls
- cobb_2035_month_vmt_fraction.xls
- cobb_2035_day_vmt_fraction.xls
- cobb_2035_hour_vmt_fraction.xls
MSAT Inventory Exercise: 
Entering Vehicle Type VMT Data

Road Type Distribution

- RoadTypeVMTFraction is the fraction of VMT (distance, not time) on each road type by a source type
Road Type Distribution

- Fractions should sum to 1 within each source type
- A Road Type 1 (Off-network) should always have a RoadTypeVMTFraction value of zero
  - No VMT on an off-network MOVES link
  - Off-network not used in MSAT analysis
- All road types appear in the template even if they were not selected in the RunSpec
  - Any VMT assigned to a road type not selected in the RunSpec will not be accounted for in MOVES output
  - Make sure that road types reflected in road type distribution are consistent with road types selected in the RunSpec

Road Type Distribution: FHWA Recommendation

- Section 4.7 of MOVES Technical Guidance
- Users should develop road type distribution data based on project-specific information
  - Should vary by year and alternative
  - Especially important if project shifts VMT from one road type to another (e.g., from arterial to freeway)
- If source type-specific data are not available, the same road type distribution can be used for all source types
  - However, in many cases, road type distributions vary for source types (e.g., transit bus vs. intercity bus, truck limitations), so source type-specific information is encouraged
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**Road Type Distribution: Using Travel Model Outputs**

- Travel model link volumes can be used to develop road type distribution fractions
  - Map to MOVES road types
    - If ramps coded separately, ramps are included as part of restricted access road
  - Calculate VMT by road type (length times volume)
  - Sum by link and road type across all time periods (MOVES road type distribution inputs do not vary by hour)
  - Calculate fractions that sum to one
    - If ramps coded separately, ramps are included as part of restricted access road
  - Repeat for each vehicle group, as needed

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**Road Type Distribution: Exercise**

- Let’s enter our road type distribution data into the CDM for our MSAT inventory exercise
- The template has been filled out with our local road type distribution and is available as file – cobb_2035_road_type_distribution.xls
- **Instructions:** Review cobb_2035_road_type_distribution.xls and import into the Road Type Distribution tab
MSAT Inventory Exercise: Entering Road Type Distribution Data

Contents of cobb_2035_road_type_distribution.xls

Browse and import the cobb_2035_road_type_distribution.xls spreadsheet
Ramp Fraction

- RampFraction is the fraction of time (not distance) spent on ramps as compared to the total time on restricted roadways and ramps
  - A restricted road type must have been selected in the Road Type panel to be able to import Ramp Fraction data
- This tab starts with a green check. A default ramp fraction of 0.08 (8%) will be applied if this fraction is not changed

Ramp Fraction: FHWA Recommendation

- Section 4.8 of MOVES Technical Guidance
- Project-specific data should be used if available, but otherwise default values of 8% are acceptable
  - May vary by alternative
    - e.g., building a new interchange probably increases ramp activity on the network
  - May vary by year
If ramps coded separately, ramp fraction can be calculated from travel model link volumes.

- Calculate freeway, ramp, and total freeway + ramp VHT.
  - Does not vary by hour or source type.
- Calculate ramp fraction.
- Separate calculation for urban and rural areas.

### Ramp Fraction: Using Travel Model Outputs

Let’s enter our ramp fraction data into the CDM for our MSAT inventory exercise.

- Our local ramp fractions for rural and urban unrestricted road types are 12%.
- The MOVES ramp fraction default (8%) must therefore be changed.

**Instructions:** Export the default data, change the fractions to 12%, and import the table into the Ramp Fraction tab.
MSAT Inventory Exercise: Entering Ramp Fraction Data

Export default data – Save as cobb_2035_ramp_fraction.xls

• cobb_2035_ramp_fraction.xls as exported with default data
MSAT Inventory Exercise: Entering Ramp Fraction Data

Change both fractions to 12% (0.12) and re-save.

Browse and import the updated RoadType worksheet.

MSAT Inventory Exercise: Entering Ramp Fraction Data
The Generic tab allows advanced users to enter data into the many tables used by MOVES to complete its calculations. In general, most users will not have a reason to enter data through this tab.

**Instructions:** We will not be adjusting any of the tables in this tab for our exercise.
Running MOVES (Executing the RunSpec)

Ensure correct input database is selected
Working with MOVES Output

MOVES Output: General

- All of the results of a MOVES run are stored in MySQL database tables
- These results can be accessed by
  - Using MOVES summary reporter
  - Using MySQL query commands and/or the MySQL Workbench (or MySQL Query Browser)
  - Using Microsoft Access with a MySQL Open Database Connectivity (ODBC)
- Any table may be exported to other applications (e.g., MS Excel) for further processing
The MOVES output database contains numerous output tables with results, input data, and other information:

- **MOVESOutput table**
  - Contains the quantity of emissions (by sourcetype, pollutant/process, etc., based on output detail selections made in the RunSpec)

- **MOVESActivityOutput table**
  - Contains the distance (useful to ensure no VMT was “lost”)

- **MOVESRun table**
  - Information about the run (e.g., date/time of run, domain and scale, units selected)

Some tables are only populated when doing an Emission Rates run (not relevant to Inventory run):

- RatePerDistance
- RatePerVehicle
- RatePerProfile

Some tables are useful for diagnostic purposes:

- ActivityType
- MOVESError
- MOVESTablesUsed
- MOVESWorkersUsed
- MOVESEventLog
Using the MOVES Post-Processing Menu

• Use this menu option only after you have completed a run
• Select an existing output database using the RunSpec used to generate the results
  – If you are interested in doing any post-processing from the Post-Processing Menu, it’s often easiest if you immediately do so upon conclusion of the run
• Options for processing output include
  – Execute any MySQL scripts that come embedded in MOVES
  – Summarize results into text files
  – Graphically represent results in a county map
Post-Processing Menu: Run MySQL Script on Output Database

- The scripts are applied to the current output database selected in the RunSpec
- You can select previous runs from the database using the MOVES Run Error Log window from the pull down Action menu
- There are several MySQL command scripts stored in the /database/OutputProcessingScripts folder of the MOVES application installation
- Users may write their own scripts and add them to the folder or add scripts obtained from other users

Post-Processing Scripts

- Read the script documentation before running MOVES
  - Project-scale scripts may require that you run MOVES in a particular way
  - Scripts may require running with a specific calculation type or certain units in the output
- Send ideas for useful scripts to mobile@epa.gov
# Post-Processing Scripts in MOVES

<table>
<thead>
<tr>
<th>Script Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>DecodeMOVESOutput.sql</td>
<td>Decodes most key fields of MOVESOutput and MOVESActivityOutput tables</td>
</tr>
<tr>
<td>EmissionRates.sql</td>
<td>Produces an output table which reports the emission results in units of mass per distance</td>
</tr>
<tr>
<td>TabbedOutput.sql</td>
<td>Produces tab-delimited output suitable for reading into an EXCEL Spreadsheet from the MOVES MySQL database output tables</td>
</tr>
</tbody>
</table>

# Post-Processing Scripts in MOVES: Project Scale

<table>
<thead>
<tr>
<th>Script Title</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO_CAL3QHC_EF.sql</td>
<td>Produces CO emission rates for use in the CAL3QHC air quality model</td>
</tr>
<tr>
<td>CO_Grams_Per_Hour.sql</td>
<td>Produces CO emission rates as grams per hour for each link (project-scale runs)</td>
</tr>
<tr>
<td>CO_Grams_Per_Veh_Mile.sql</td>
<td>Produces CO emission rates as grams per vehicle-mile for each link (project-scale runs)</td>
</tr>
<tr>
<td>PM10_Grams_Per_Hour.sql</td>
<td>Produces PM10 emission rates as grams per hour for each link (project-scale runs)</td>
</tr>
<tr>
<td>PM10_Grams_Per_Veh_Mile.sql</td>
<td>Produces PM10 emission rates as grams per vehicle-mile for each link (project-scale runs)</td>
</tr>
<tr>
<td>PM25_Grams_Per_Hour.sql</td>
<td>Produces PM2.5 emission rates as grams per hour for each link (project-scale runs)</td>
</tr>
<tr>
<td>PM25_Grams_Per_Veh_Mile.sql</td>
<td>Produces PM2.5 emission rates as grams per vehicle-mile for each link (project-scale runs)</td>
</tr>
</tbody>
</table>
To minimize post-MOVES spreadsheet errors, use summary reporter in the post-processing menu to generate reports of results.

- Can generate reports in multiple levels of detail (e.g., all vehicle types combined, and by individual vehicle type)
Post-Processing Menu: Summary Report

- Uses the output tables in the database referenced in the current RunSpec
- Reports output emissions and activity in varying levels of detail, based on selections by the user

Other Post-Processing Options

- Export the data using MySQL script
- Export the data using MySQL Workbench or MySQL Query Browser
  - CSV
  - MS Excel
  - PLIST
- Use the data from MS Access using the ODBC
MySQL Workbench

- Provided with the MOVES model installation suite
- Oracle’s new integrated environment for:
  - Database administration (replacing MySQL Administrator)
  - SQL development (replacing MySQL Query Browser)
- Workbench maintains the same basic functionality of Query Browser for MOVES-related database work

MySQL Workbench: Password

1. Click
2. If prompted, enter “moves” in the password field. To suppress subsequent prompts, click Save password in vault. Click OK.
MySQL Workbench: Layout

From left to right, these buttons are:

- **Open a SQL Script File**: Loads a saved SQL script to be ready for execution
- **Save SQL Script to File**: Saves the current SQL script to a specified file
- **Execute SQL Script**: Executes the selected portion of the query, or the entire query if nothing is selected
- **Execute Current SQL Script**: Execute the statement under the keyboard cursor
- **Explain**: Execute the EXPLAIN command on the query after the keyboard cursor
- **Stop the Query being Executed**: Halts execution of the currently executing SQL script
- **Toggle Whether Execution of SQL Script should Continue after Failed Statements**: If the red “breakpoint” circle is displayed, the script terminates on a statement that fails. If the button is depressed so that the green arrow is displayed, execution continues past the failed code, possibly generating additional results sets. In either case, any error generated from attempting to execute the faulty statement is recorded in the Output tab sheet
- **Commit**: Commits the current transaction*
- **Rollback**: Rolls back the current transaction*
- **Toggle Auto-Commit Mode**: If selected, each statement will be committed independently*
- **Beautify SQL**: Beautify/reformat the SQL script
- **Find Panel**: Show the Find panel for the editor
- **Invisible Characters**: Toggle display of invisible characters, such as new lines, tabs, or spaces
- **Wrapping**: Toggles the wrapping of long lines in the SQL editor window

*Note: All query tabs in the same connection share the same transactions; to have independent transactions, a new connection must be open
MySQL Workbench: Basics

Expand the desired output database (Schemas) by clicking on the appropriate button.

NOTE: The 1000 row limit can be toggled on and off with the highlighted button.

To quick view a table, right-click the table name and click Select Rows – Limit 1000 . . .

MySQL Workbench: Basics
MySQL Workbench: Basics

... or type and run a query

Query scripts may be saved or loaded using the highlighted icons
Parts of query scripts may be saved using the Snippets Tab and Snippets Pallet (highlighted)

Table navigation, sorting, exporting, and search tools
MySQL Workbench: Basics

Click the Export Resultset icon to export the current output set.

Note: Uncheck the Select Rows – Limit 1000 button to export the entire output set if greater than 1000 rows.

The MySQL Query Browser

- Windows tool for viewing databases, executing queries, and editing tables
- Results can be exported as .csv or MS Excel files
- Built-in Help files
- Query history recorded, so you can repeat queries without retyping them
- Tables can be edited directly, rather than using MySQL commands
MySQL Query Browser

- No longer provided with the MOVES model suite
- Can be installed from older versions of EPA’s MOVES model installation suite
- Can also be downloaded from the MySQL web site: http://downloads.mysql.com/archives/query/

Exploring MOVES Databases with Query Browser

- **Instructions:** Open the MySQL Query Browser
  - Start/Programs/MySQL/MySQL Query Browser
  - Make sure “localhost” is specified (might not be after initial installation) and click “OK”
    - Click “Ignore” on warning message about schema
MySQL Query Browser Screen

Double-click on database symbol to open it and show the tables
Viewing County-scale Inventory
Results: “movesoutput” table

Viewing County-scale Inventory
Results: “movesactivityoutput”
Simple MySQL Queries

- Queries can be typed into the Query Area
- Queries can also be auto-generated by dragging and dropping the table name into Data area
  - Dragging to the Data Area creates and executes a “select all” query
  - This can be a useful shortcut
- Click the button or hit CTL/ENTER to execute queries

Other Useful MySQL Features

- Exporting ResultSet
- Viewing history
- Bookmarking queries
- Saving queries
Using MySQL Query Browser:
Exporting Resultsets

Using MySQL Query Browser:
Query History
Using MySQL Query Browser: Bookmarks

Can bookmark queries for future reference.

Using MySQL Query Browser: Saving Queries
Copying and sending MySQL databases

- Databases may be copied and zipped for email and review, or archiving

- All input and output databases are stored as folders on your hard drive
  - C:\Users\Public\MySQL Server 5.6\data

FHWA Resource Center
Online MySQL Training

- https:\\connectdot.connectsolutions.com\mysql_training_info\
Purpose

- Capture the anticipated changes in MSAT emissions as a direct result of a proposed project
- Provide a framework for an objective quantitative assessment, minimizing uncertainty and bias
- Keep the analysis manageable by analyzing all segments associated with the project plus those segments expecting meaningful changes in emissions (e.g., ± 10% or more)
Define the network based on available project-specific information such as a supporting technical traffic analysis. Recommended Metrics:
- Changes of ± 5% or more in AADT on congested highway links of LOS D or worse
- Changes of ± 10% or more in AADT on uncongested highway links of LOS C or better
- Changes of ± 10% or more in travel time
- Changes of ± 10% or more in intersection delay

Distinguish modeling artifacts from real effects.
Affected Transportation Network

Legend

Affected Network Links
Study Corridor

Affected Transportation Network
Affected Transportation Network

- Process a link table for the affected transportation network to produce MOVES input tables of project-specific data:
  - Average Speed Distribution
  - HPMS VType Year
  - Road Type Distribution
  - Ramp Fraction
The minimum Project Traffic Data needed to complete a quantitative MSAT analysis are:

- Link ID
- MOVES Road Type
- Length
- Annual Average Daily Traffic (AADT)
- % Trucks
- Peak/Off-peak Travel Fractions
- Peak/Off-peak Travel Speeds

for each of the links in the Affected Transportation Network (example in AffectedNetworksLinks.xlsx)
This Class Exercise is based on the minimum Project Traffic Data required to complete a quantitative MSAT analysis.

More extensive link data may be available for some projects, including:
- Vehicle-miles of travel (VMT);
- Vehicle-hours of travel (VHT);
- AADT or VMT by one or more vehicle types;
- AADT or VMT by time period; and/or
- Speed or VHT by one or more vehicle types.

Make direct use of such project-specific data in lieu of developing data from base information as demonstrated in this class exercise.
Class Exercise

• Divide into Teams to perform three tasks
• Task 1 – Populate the HPMSVTypeYear tab in the AffectedNetworkLinks.xlsx workbook by completing the following 6 steps
  – Step 1: Add a column to compute the daily VMT for each link
    Daily VMT = AADT (vpd) \times Distance (mi)
  – Step 2: Add a column to compute the daily VMT by MOVES SourceTypeID for each link
    • Use data in the CobbSourceTypeVMT tab to allocate link VMT by SourceTypeID based on the HDV ratio
    • HDVs include SourceTypeIDs 41, 42, 43, 51, 52, 53, 54, 61, 62

Class Exercise

– Step 3: Compute the sum total daily VMT by SourceTypeID \((\Sigma \text{Daily VMT}_{\text{SourceTypeID}})\) for the affected network
– Step 4: Compute the total annual VMT by SourceTypeID for the affected network
  \[\text{Annual VMT} = \text{Daily VMT} \times 365 \text{ days/yr}\]
– Step 5: Compute the total annual VMT by HPMS vehicle type (HMPSVTypeID) for the affected network

<table>
<thead>
<tr>
<th>HPMSVTypeID</th>
<th>MOVES SourceTypeID</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>11</td>
</tr>
<tr>
<td>25</td>
<td>21 + 31 + 32</td>
</tr>
<tr>
<td>40</td>
<td>41 + 42 + 43</td>
</tr>
<tr>
<td>50</td>
<td>51 + 52 + 53 + 54</td>
</tr>
<tr>
<td>60</td>
<td>61 + 62</td>
</tr>
</tbody>
</table>
Class Exercise

- Step 6: Populate the HPMSVTypeYear tab

<table>
<thead>
<tr>
<th>HPMSVTypeID</th>
<th>yearID</th>
<th>HPMSBaseYearVMT</th>
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<tbody>
<tr>
<td>10</td>
<td>2035</td>
<td>41375904</td>
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<tr>
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<td>1952816167</td>
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<tr>
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<td>49154812</td>
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<tr>
<td>50</td>
<td>2035</td>
<td>143126902</td>
</tr>
<tr>
<td>60</td>
<td>2035</td>
<td>90740845</td>
</tr>
</tbody>
</table>

Class Exercise

- Task 2 – Populate the RoadTypeDistribution tab in the AffectedNetworkLinks.xlsx workbook by completing the following 4 steps
  - Step 1: Based on the computations added to the AffectedNetworkLinks tab for Task 1, sort rows by MOVES RoadTypeID
  - Step 2: Compute the sum total daily VMT by SourceTypeID segregated by RoadTypeID \((\sum \text{ Daily VMT}_{\text{SourceTypeID, RoadTypeID}})\)
  - Step 3: Compute the RoadTypeVMTFraction by SourceTypeID segregated by RoadTypeID

\[
\text{RoadTypeVMTFraction} = \frac{\sum \text{ Daily VMT}_{\text{SourceTypeID, RoadTypeID}}}{\sum \text{ Daily VMT}_{\text{SourceTypeID}}}
\]
Class Exercise

– Step 4: Populate the RoadTypeDistribution tab

<table>
<thead>
<tr>
<th>sourceTypeID</th>
<th>roadTypeID</th>
<th>VMTFraction</th>
<th>sourceTypeID</th>
<th>roadTypeID</th>
<th>VMTFraction</th>
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</thead>
<tbody>
<tr>
<td>11</td>
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<td>11</td>
<td>5</td>
<td>0.138822</td>
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<td>5</td>
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<td>4</td>
<td>0.944013</td>
<td>62</td>
<td>5</td>
<td>0.055987</td>
</tr>
</tbody>
</table>

Task 3 – Populate the AvgSpeedDistribution tab in the AffectedNetworkLinks.xlsx workbook by completing the following 7 steps

– Note: The entire template is included to show the amount of data required to populate an AvgSpeedDistribution spreadsheet. For the Class Exercise, however, compute the average speed distribution for SourceTypeID = 21; RoadTypeID = 4, 5; HourDayID = 75; and AvgSpeedBinIDs = 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16
Class Exercise

- Step 1: Sort rows by MOVES RoadTypeID
- Step 2: Add a column to compute the VHT during the AM peak period for SourceTypeID = 21 for each link
\[ VHT_{AM,\text{SType}21} = \text{Volume}_{AM,\text{SType}21} \times \text{Distance (mi) / Speed}_{AM} \text{ (mph)} \]
- Step 3: Add 16 columns, one to represent each AvgSpeedBin

<table>
<thead>
<tr>
<th>AvgSpeed BinID</th>
<th>AvgBin Speed</th>
<th>AvgSpeedBinDesc</th>
<th>AvgSpeed BinID</th>
<th>AvgBin Speed</th>
<th>AvgSpeedBinDesc</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2.5</td>
<td>speed &lt; 2.5mph</td>
<td>9</td>
<td>40</td>
<td>37.5mph &lt;= speed &lt; 42.5mph</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
<td>2.5mph &lt;= speed &lt; 7.5mph</td>
<td>10</td>
<td>45</td>
<td>42.5mph &lt;= speed &lt; 47.5mph</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>7.5mph &lt;= speed &lt; 12.5mph</td>
<td>11</td>
<td>50</td>
<td>47.5mph &lt;= speed &lt; 52.5mph</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>12.5mph &lt;= speed &lt; 17.5mph</td>
<td>12</td>
<td>55</td>
<td>52.5mph &lt;= speed &lt; 57.5mph</td>
</tr>
<tr>
<td>5</td>
<td>20</td>
<td>17.5mph &lt;= speed &lt; 22.5mph</td>
<td>13</td>
<td>60</td>
<td>57.5mph &lt;= speed &lt; 62.5mph</td>
</tr>
<tr>
<td>6</td>
<td>25</td>
<td>22.5mph &lt;= speed &lt; 27.5mph</td>
<td>14</td>
<td>65</td>
<td>62.5mph &lt;= speed &lt; 67.5mph</td>
</tr>
<tr>
<td>7</td>
<td>30</td>
<td>27.5mph &lt;= speed &lt; 32.5mph</td>
<td>15</td>
<td>70</td>
<td>67.5mph &lt;= speed &lt; 72.5mph</td>
</tr>
<tr>
<td>8</td>
<td>35</td>
<td>32.5mph &lt;= speed &lt; 37.5mph</td>
<td>16</td>
<td>75</td>
<td>72.5mph &lt;= speed &lt; speed</td>
</tr>
</tbody>
</table>

Class Exercise

- Step 4: Assign the VHT computed in Step 2 to the appropriate AvgSpeedBin added in Step 3
- Step 5: Compute the sum total VHT by AvgSpeedBinID segregated by RoadTypeID (\( \sum VHT_{\text{AvgSpeedBinID, RoadTypeID}} \))
- Step 6: Compute the AvgSpeedFraction by AvgSpeedBinID segregated by RoadTypeID
\[ \text{AvgSpeedFraction} = \frac{\sum VHT_{\text{AvgSpeedBinID, RoadTypeID}}}{\sum VHT_{\text{AvgSpeedBinID}}} \]
### Step 7: Populate the AvgSpeedDistribution tab

<table>
<thead>
<tr>
<th>SourceTypeID</th>
<th>RoadTypeID</th>
<th>Hour</th>
<th>DayID</th>
<th>AvgSpeedBinID</th>
<th>AvgSpeed</th>
<th>AvgSpeedFraction</th>
<th>SourceTypeID</th>
<th>RoadTypeID</th>
<th>Hour</th>
<th>DayID</th>
<th>AvgSpeedBinID</th>
<th>AvgSpeed</th>
<th>AvgSpeedFraction</th>
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<td>4</td>
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<td>75</td>
<td>16</td>
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<td></td>
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</table>
Using MOVES at the County-scale versus Project-scale for MSAT Analyses

Overview

- Pros and cons of using emissions rates runs for MSAT analysis
- Using rates output to calculate MSAT emissions
- MOVES RunSpecs and inputs for rates
- Pros and cons of using Project Scale for MSAT analysis
- MOVES RunSpecs and inputs for Project scale runs
3 Approaches for Modeling MSATs with MOVES

- County Scale, Inventory
- County Scale, Rates
- Project Scale, Inventory

Summary: RunSpecs Needed for a County/Inventory MSAT Approach

- One RunSpec for each year and alternative
  - The parameters of the RunSpecs for each year are identical, but each references a different input database (by alternative)
- If DPM being modeled separately from the other MSATs, then two RunSpecs for each year and alternative
  - One RunSpec includes all vehicle types, and the non-DPM MSAT pollutant/process selections
  - The other RunSpec includes only the diesel vehicle types, and DPM pollutant/process selections
  - CDM inputs are the same (need to start with total VMT); can use the same input databases for DPM and non-DPM runs
Pros and Cons of County Rates runs for MSAT Analysis

- Less pre-processing of travel data is needed to generate inputs
  - Speed, VMT, road type distribution inputs don’t have to be project-specific, can even be defaults in most cases
- Considerably more post-processing of MOVES output is needed to generate MSAT inventories for the project alternatives
- Rates runs also take longer

Types of estimates generated from a MOVES “Rates” run

- Rateperdistance
- Ratepervehicle
- Rateperprofile
- For NEPA MSAT emissions estimates, running emissions (rateperdistance) are used
  - Other forms of rates reflect starts, evaporative emissions from parked cars, truck extended idling, and other non-highway emissions, which are not included in MSAT analysis
Detail in MOVES rates

- Rates produced for each of 16 speed bins, 4 road types, 2 day types, 24 hours
  - Can add even more detail, such as fuel type, source type, . . .
- Rates produced for up to 12 months, depending on approach to estimate annual emissions
- Separate runs (or more post-processing) needed for DPM versus the other MSATs
  - DPM only comes from diesel vehicles

Creating a RunSpec for a Rates Run – Scale

- Select “Onroad”
- Select “County”
- Select “Emission Rates”

MOVESScenarioID is required but will not impact results
Time Spans: Manageable Approach for MSAT Rates RunSpec

- Model 4 hours of a weekday (corresponding to AM Peak, Midday, PM Peak, and Overnight); could be fewer, depending on what traffic data are available
  - Will require separate RunSpecs, since MOVES can’t model non-contiguous hours
- Model 4 months to represent seasons (these can all be in the same RunSpec)
  - need to “grow” inventory to annual basis in post-processing

Creating a RunSpec for a Rates Run – Other Selections

- Other selections are the same as for an inventory run
- Diesel particulate matter:
  - PM10 total exhaust rates are needed for only diesel vehicles, while other MSATs are produced by all vehicle types
  - Rates need to be multiplied by the proper VMT (by fuel type, in this case)
  - Easiest approach is use a separate RunSpec (or set of RunSpecs) with only diesel vehicles selected in “Vehicle/Equipment”, and multiply these rates by diesel VMT only
    - If default diesel fractions are used in the Fuel Type and Technologies inputs, then the fraction of diesel VMT can be calculated by doing a National scale run for the year and county, and requesting “distance” and “fuel type” and “road type” in the output
Creating a RunSpec for a Rates Run – Other Selections

- Remaining MSATs are calculated by doing run(s) with all fuel types, and these rates are multiplied by total VMT (not diesel VMT)

Summary: RunSpecs needed for a Rates approach

- Base year
  - One RunSpec for all fuel types for each time period
  - One RunSpec for diesel only for each time period
  - Each RunSpec includes all four seasons
- Repeat for each analysis year
- Unlike Inventory approach, separate RunSpecs are not needed for each alternative
  - Possible exception—if there are major changes in ramp fraction between alternatives
Creating an Input Database for a Rates Run

- In general, inputs for rates runs are placeholders, and just need to be reasonable for the area
  - The MSAT inventory is calculated outside of MOVES, so exact VMT, speed, etc. is not important as a MOVES input
  - Use local data if available, otherwise national defaults
- Possible exception: ramp fraction
  - This affects the restricted access roadway rates
  - Can either include ramp VMT with associated mainline VMT, and use emissions rate based on mainline speed; or, set up MOVES run to report separate output for ramps (Road Type panel) and then apply ramp rates to ramp VMT based on ramp speed

Working with Rates Output

- Rates output cannot be accessed via the MOVES Summary Reporter
  - Query/export from your MySQL output database
- Units in grams per vehicle-mile (select these in General Output panel)
- Output rate per distance table reports a rate for each speed bin
  - Rates will always be reported for each speed bin 1-16 corresponding to 0 mph to 72.5+ mph
Inventory is calculated by multiplying the link VMT at a given speed by the emission rate for that speed, road type and time period, and repeating for all of the time periods (and months) in the analysis.

In general, rates cannot be averaged or summed in order to simplify the post-MOVES algebra—need to multiply proper rates by proper VMT.

- Rates for related processes can be summed (e.g., running exhaust and crankcase running exhaust).
- Rates between two 5mph speed bins can be interpolated to get a rate for an exact speed.

Be sure to use the correct VMT in calculations of DPM and the other MSATs.
MOVES Project Scale

- Project scale designed for link level analysis
  - CO and PM “Hot-spot” analysis for conformity
  - NEPA
  - Roadway/Intersection level energy and GHG analysis
- Link-specific data must be entered when the Project scale is selected
- Data can be exported or imported with the Project Data Manager (PDM)

Guidance and Training Available

- These slides don’t reflect technical or policy guidance for conformity uses of MOVES at the Project Scale
- EPA has developed guidance for use of MOVES in project-scale CO and PM analyses
  - www.epa.gov/otaq/stateresources/transconf/policy.htm
- Training materials also available for the 3-day PM hotspot modeling course
  - www.epa.gov/otaq/stateresources/transconf/training3day.htm
More About Project Scale

- Utilizes same MOVES emission rates and correction factors as county and national scale
- It does NOT utilize the default MOVES growth, VMT or population data
  - These must be supplied by the user
- It allows the user to specify only one combination of
  - County
  - Year
  - Month
  - Hour
  per run

Pros and Cons of Project Scale runs for MSAT Analysis

- More MOVES runs needed
  - because each run can cover only one hour in one month
- Less pre-processing of travel data needed compared to County Inventory
  - because link data can be used directly, rather than converting it into MOVES distributions
- Less post-processing than Rates, but more than County Inventory
  - emissions for individual links need to be summed across hours and months to estimate annual emissions for the network
RunSpecs for Project Scale

Model 4 hours of a weekday (corresponding to AM Peak, Midday, PM Peak, and Overnight); could be fewer, depending on what traffic data are available

- Will require separate RunSpecs, since MOVES can only model one hour at the Project scale

Model 4 months to represent seasons (these can all be in the same RunSpec)

- Will also require separate RunSpecs, since MOVES can only model one month at the Project scale

Time Spans at Project Scale
Output Emissions Detail:
Select “Fuel Type” to get DPM

Project Scale Inputs

- Links
- Off-Network
  - not used in MSAT analysis
- Link Source Types
- Age Distribution
- Meteorology Data
- Fuel Inputs
- I/M
  - only required for areas with I/M
Project Scale Inputs

- Operating Mode Distribution
  - optional advanced traffic input for highway projects
  - also required if modeling Off-Network link
- Link Drive Schedules
  - optional advanced traffic input for highway projects

Project Scale Inputs

- Links
- Off-Network
- Link Source Types
- *Age Distribution*
- *Meteorology Data*
- *Fuel Inputs*
- *I/M*
- Operating Mode Distribution
- Link Drive Schedules

Inputs common to both MOVES County scale and Project scale analyses
Project Scale Inputs

- **Links**
- **Off-Network**
- **Link Source Types**
- Age Distribution
- Meteorology Data
- Fuel Inputs
- I/M
- **Operating Mode Distribution**
- **Link Drive Schedules**

Inputs unique to MOVES Project scale analyses

---

Project Data Manager

- Similar to County Data Manager used in Inventory and Rates runs, but with different inputs
Links Inputs

- LinkID: Each link in Project must be entered
- CountyID: MOVES five digit county code
- ZoneID: county ID with zero at the end
- RoadTypeID: MOVES roadtype code
- Link Length: in miles
- Link Volume: total traffic volume in one hour
- Link Average Speed: in mph
- Link Description: optional text field
- Link Grade: in percent grade (100% = 45 degree slope)
  - modelers often use zero for all links
Link Source Type Inputs

• **LinkID**
  - Must include all LinkIDs defined in Links Input

• **SourceType**
  - Must include all source types selected in On Road Vehicle/Equipment panel
    - e.g., all 13 source types, unless some don’t operate on specific links

• **SourceTypeHourFraction**
  - Specify vehicle mix (fraction of VHT) on each link
  - Fractions must sum to “1” for each linkID
Defining Vehicle Activity in MOVES

- Users may choose one or more options:
  - Define a link average speed (through the “Links table”)
    - MOVES includes default OpMode distributions based on typical driving cycles
    - Appropriate for MSAT analysis
  - Enter a link specific drive cycle
    - User defines a second-by-second drive cycle for each link
  - Directly enter a link specific OpMode distribution
    - Precisely describes distribution of activity on a link (fraction of time spent in each OpMode bin)
    - OpMode distribution is required if modeling an off-network link

Summary of RunSpecs and Input Databases Needed

- If modeling 4 hours (time periods) and 4 months, need 16 RunSpecs per calendar year
- Will also need a unique input database for each time period and calendar year and project alternative
  - because traffic input data vary by year, time of day and alternative
- Can run multiple input databases (one for each alternative) through the same RunSpec, as long as the other conditions are the same
  - e.g., traffic and met inputs are for the time period listed in the RunSpec (explain this in the Description panel)
Working with Project Output

- Summary reporter does not report emissions by link
  - Will sum emissions for all links
- Calculate DPM based on diesel VMT on links, and other MSATs based on all VMT on links
- Need to “grow” inventory to annual basis in post-processing
  - Multiply emissions for each representative hour by the # of hours in the time period to get daily emissions
  - Multiply emissions for each representative day (seasons represented by one month) to get annual emissions

Summary: 3 Approaches for Modeling MSATs with MOVES

- County Scale, Inventory
  - Pre-processing of travel data to produce inputs
  - No post-processing (MOVES produces the inventory)
  - Use of Summary Reporter for results
- County Scale, Rates
  - Very little pre-processing of inputs
  - Considerable post-processing to assemble inventory
- Project Scale, Inventory
  - Some pre-processing of input data
  - Some post-processing of outputs
Using MOVES for Energy or GHG Analyses

Overview

- Available guidance
- Adding GHGs and energy to MOVES RunSpecs and inputs for MSAT runs
- FHWA tool for construction and maintenance GHGs and energy
- Reporting results in NEPA documents
No federal guidance currently requires GHG analysis in NEPA documents

- Analysis to date has been a result of state requirements, responses to scoping comments, etc.
- If future CEQ guidance does require this analysis, FHWA’s preference will be PEL approaches based on planning-level analysis

Energy analysis has always been required in NEPA, but qualitative analysis has been sufficient

These slides provide technical recommendations on modeled GHG and energy analysis with MOVES, but the analyses themselves are optional

MOVES was designed from the start as an energy model

MOVES validated against national fuel sales data

Compared to MOBILE6 and older models, MOVES energy/GHG estimates take congestion into account, and grade (at the Project scale)
EPA MOVES GHG Guidance

• In 2012, EPA issued guidance on use of MOVES for inventories of GHGs and energy consumption
  – www.epa.gov/otaq/stateresources/420b12068.pdf
• Oriented toward regional inventory analysis, but much of it also applicable to project-level
• MOVES2010b didn’t include newest LD and HD fuel economy/GHG standards, but MOVES2014 does

Adding energy/GHG analysis to MSAT analysis

• MSAT RunSpecs already require Total Energy and Total Gaseous Hydrocarbons (chained pollutants)
• For GHGs, add:
  – Methane
  – Nitrous Oxide
  – Atmospheric CO2
• “CO2 Equivalent” will convert emissions of these three pollutants to equivalent emissions of CO2
Black Carbon

- If you want to model “black carbon” as a GHG, use “Primary PM10 – Elemental Carbon” from DPM runs
- BC is not included in CO2e calculations (no Global Warming Potential has been established for black carbon)

Adding energy/GHG analysis to MSAT analysis

- These pollutants can be added to existing MSAT RunSpecs; don’t need separate runs
- County- or project-level inputs remain the same (no additional input data)
- Can include these pollutants in any necessary post-processing (e.g., from using MOVES in Rates mode)
Electricity in MOVES

- MOVES allows some but not all vehicle types to be EVs
  - EVs in MOVES are full-time grid-charged electric vehicles, not hybrids
- Can estimate electricity consumption if
  - Electricity selected as a fuel type
  - “Fuel type and technology” inputs include EV fractions (default is zero)
  - “Fuel Type” selected in Output Emissions Detail

Construction and Maintenance
Energy/GHGs: FHWA ICE Tool

- FHWA has developed a spreadsheet tool, the Infrastructure Carbon Estimator, to estimate energy and CO2 from construction and maintenance
- Covers construction materials, equipment fuel use, maintenance materials and fuel use
- Estimates emissions/energy reductions from mitigation strategies
- Can be used to estimate payback periods (e.g., when do energy savings from the project offset construction energy?)
Construction and Maintenance
Energy/GHGs: FHWA ICE Tool

- Tool and User Guide available at:
  www.fhwa.dot.gov/environment/climate_change/mitigation/publications_and_tools/carbon_estimator/index.cfm

Using the Tool: Step 1

- Step 1: Input general information about your project/plan.

Project location (state) | AK
Project lifetime (years) | 20

Roadway Routine Maintenance
- Total existing centerline miles: 50,000
- Total existing lane miles: 200,000
- Total newly-constructed centerline miles: 1.75
- Total newly-constructed lane miles: 7

Rail, Bus, and Bicycle Routine Maintenance
- Total existing track miles of light rail: 30
- Total existing track miles of heavy rail: 50
- Total newly-constructed track miles of rail: 0
- Total existing lane miles of bus rapid transit: 20
- Total newly-constructed lane miles of bus rapid transit: 0
- Total existing lane miles of bicycle lanes: 50
- Total newly-constructed lane miles of bicycle lanes: 1
Using the Tool: Step 2

Step 2: Input information about construction and maintenance activities

<table>
<thead>
<tr>
<th>Facility type</th>
<th>New Roadway (lane miles)</th>
<th>Construct Additional Lane (lane miles)</th>
<th>Re-Alignment (lane miles)</th>
<th>Lane Widening (lane miles)</th>
<th>Shoulder Improvement (centerline miles)</th>
<th>Reconstruct Pavement (lane miles)</th>
<th>Resurface Pavement (lane miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rural Interstates</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>50</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Rural Principal Arterials</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>0</td>
<td>30</td>
</tr>
<tr>
<td>Rural Minor Arterials</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Rural Collectors</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>20</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Urban Interstates / Expressways</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>40</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Urban Principal Arterials</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Urban Minor Arterials / Collectors</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

Using the Tool: Step 3

Step 3: Input information about construction delay

- Total project-days of lane closure
- Average daily traffic per directional segment for facilities requiring lane closure
- Percentage of facility lanes closed during construction: 50%
Using the Tool: Step 4

Step 4: Input mitigation strategies

<table>
<thead>
<tr>
<th>Energy / GHG reduction strategies</th>
<th>Baseline deployment</th>
<th>Planned deployment</th>
<th>Max potential deployment</th>
<th>Applied to</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alternative fuels and vehicle hybridization</td>
<td>0%</td>
<td>10%</td>
<td>44%</td>
<td>Fuel use by maintenance equipment</td>
</tr>
<tr>
<td>Hybrid maintenance vehicles and equipment</td>
<td>0%</td>
<td>10%</td>
<td>100%</td>
<td>Fuel use by maintenance equipment</td>
</tr>
<tr>
<td>Switch from diesel to B20 in maintenance vehicles and equipment</td>
<td>0%</td>
<td>10%</td>
<td>100%</td>
<td>Fuel use by maintenance equipment</td>
</tr>
<tr>
<td>Combined hybridization/B20 in maintenance vehicles and equipment</td>
<td>0%</td>
<td>10%</td>
<td>44%</td>
<td>Fuel use by maintenance equipment</td>
</tr>
<tr>
<td>Vegetation management</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternative vegetation management strategies (hardscaping, alternative mowing, integrated roadway/vegetation management)</td>
<td>No</td>
<td>Yes</td>
<td>N/A</td>
<td>Fuel use by vegetation management equipment</td>
</tr>
<tr>
<td>Snow fencing and removal strategies</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Alternative snow removal strategies (snow fencing, wing plows)</td>
<td>No</td>
<td>Yes</td>
<td>N/A</td>
<td>Fuel use by snow removal equipment</td>
</tr>
<tr>
<td>In-place roadway recycling</td>
<td>0%</td>
<td>0%</td>
<td>99%</td>
<td>Asphalt and fuel use by construction equipment in roadway resurfacing and BRT conversions</td>
</tr>
<tr>
<td>Cold in-place recycling</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Using the Tool: Step 5

Step 5: View impacts of construction and maintenance activities

### Annualized energy use (mmBTUs), per year over 20 years

<table>
<thead>
<tr>
<th>Unmitigated</th>
<th>Roadway - new construction</th>
<th>Roadway rehabilitation</th>
<th>Roadway - total</th>
<th>Bridges</th>
<th>Rail, bus, bicycle, ped.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream Energy Materials</td>
<td>89,975</td>
<td>152,838</td>
<td>242,813</td>
<td>24,643</td>
<td>178,067</td>
<td>445,523</td>
</tr>
<tr>
<td>Direct Energy Construction Equipment Routine Maintenance</td>
<td>33,942</td>
<td>27,079</td>
<td>60,021</td>
<td>10,747</td>
<td>61,606</td>
<td>132,374</td>
</tr>
<tr>
<td>Total</td>
<td>123,917</td>
<td>179,917</td>
<td>302,834</td>
<td>35,390</td>
<td>239,673</td>
<td>736,482</td>
</tr>
</tbody>
</table>

### Annual GHG emissions (MT CO2e), per year over 20 years

<table>
<thead>
<tr>
<th>Unmitigated</th>
<th>Roadway - new construction</th>
<th>Roadway rehabilitation</th>
<th>Roadway - total</th>
<th>Bridges</th>
<th>Rail, bus, bicycle, ped.</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upstream Emissions Materials</td>
<td>5,626</td>
<td>9,276</td>
<td>14,902</td>
<td>2,065</td>
<td>12,507</td>
<td>29,474</td>
</tr>
<tr>
<td>Direct Emissions Construction Equipment Routine Maintenance</td>
<td>2,402</td>
<td>1,975</td>
<td>4,377</td>
<td>784</td>
<td>4,491</td>
<td>9,652</td>
</tr>
<tr>
<td>Total</td>
<td>8,028</td>
<td>11,251</td>
<td>19,279</td>
<td>2,849</td>
<td>16,998</td>
<td>50,690</td>
</tr>
</tbody>
</table>
Can use similar techniques to report GHG results as used for MSAT results (e.g., trend graphs)
Include a point of reference
   - Many FHWA NEPA docs compare project emissions to state and global emissions

Reporting results in NEPA docs: energy

- Energy results can be reported in MOVES units (e.g., million Btus), or converted to fuel-based units (e.g., gallons of gasoline equivalent (GGe))
- Conversion factor: 1 gallon gasoline = 124,000 Btu
  - Can also do this conversion for each of the fuel types, if you need that much detail
- Can also convert GGe estimates to cost estimates, based on price of gasoline
Documenting MOVES Work for Reviewers and the Project Files

Best practices

• Use naming conventions
  – Use consistent names for RunSpecs, input spreadsheets, input databases, output databases so you (and your reviewers) know which files go together
• Use descriptions
  – Use the Description panel in the RunSpec to explain what each run does; can also type descriptions in the CDM before importing each data item
When sending a group of files for review, include a brief “readme” file explaining what each file is (easier if you’ve created the master list of RunSpecs and inputs described earlier)

- Explain any anomalies (e.g., an output database that contains more than one run when others don’t, etc.)

Managing files

- Group of spreadsheets for each run, or one spreadsheet
- Back up/archive files when complete
- RunSpecs, data spreadsheets, input and output databases can be stored on external media when no longer needed
- Also save the MOVES install package you used and any updated default database
  - In case you have to duplicate your work years later
Session 3: Using MOVES for Highway Air Dispersion Modeling

Session Outline

- Setting Up a MOVES Runspec
  - Pertinent navigation panels
- MOVES Project Data Manager
  - Specifying project data
- Class Exercise
  - Constructing a CO speed look-up table
Setting Up a MOVES Runspec

Construct a MOVES runspec by advancing through all navigation panels in sequence before launching the Project Data Manager.

Pertinent Navigation Panels
For Model, Select “Onroad”

For Domain/Scale, Select “Project”

For Calculation Type, “Inventory” is typically selected for the AERMOD model. “Emission Rates” is typically selected for the CAL3 models.
Scale

• **TIP:**
  - The same result will be obtained for a simulation using either the Inventory or Emission Rates Calculation Type by entering lengths of 1 mi and volumes of 1 vph on the Links Project Data Manager tab

Time Spans

The Time Aggregation Level is fixed at “Hour”

As a result, only one selection can be made for:
  • “Years”
  • “Months”
  • “Days”
  • “Hours”
Geographic Bounds

A single county must be specified for the Region: “Zone & Link” or “Custom Domain” (e.g., aggregate county) . . .

Geographic Bounds:
Selecting the Project County

• If a project spans multiple counties, users have three options:
  – If the fuel supply and age distribution of vehicles in the fleet are the same for all of the counties, select the county in which the majority of the project area is located;
  – If not, separate the project into multiple parts (each of which is in a separate county) and do separate MOVES runs for each part; or
  – Use the custom domain option to model one unique area that represents all the project counties

... the Project Data Manager may be entered here; but wait until information is specified in all panels.
### Pollutants and Processes: On Road Components

<table>
<thead>
<tr>
<th>Description</th>
<th>Scale</th>
<th>Time/Space</th>
<th>Geographic/Regional</th>
<th>Vehicular/Equipment</th>
<th>Road Type</th>
<th>Roadside Features</th>
<th>Strategies</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Particulate Matter</td>
<td>Tonnage</td>
<td>Hour</td>
<td>Local</td>
<td>Truck, Bus</td>
<td>Heavy, Light</td>
<td>Roadside</td>
<td>Routing</td>
<td>Impaired Biodiversity</td>
</tr>
<tr>
<td>Sulfur Dioxide</td>
<td>Tonnage</td>
<td>Year</td>
<td>National</td>
<td>Airplane</td>
<td>Domestic</td>
<td>Residential</td>
<td>Congestion Mitigation</td>
<td>Dust Suppression</td>
</tr>
<tr>
<td>Nitrogen Oxides</td>
<td>Tonnage</td>
<td>Day</td>
<td>Statewide</td>
<td>Motorcycle</td>
<td>Sport Utility Vehicle</td>
<td>Urban</td>
<td>Odor Control</td>
<td>Aftermarket Parts</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>Tonnage</td>
<td>Season</td>
<td>International</td>
<td>Hybrid</td>
<td>Electric Vehicle</td>
<td>Rural</td>
<td>Emissions Reduction</td>
<td>Advanced Gearbox</td>
</tr>
<tr>
<td>Hydrocarbons</td>
<td>Tonnage</td>
<td>Month</td>
<td>Overseas</td>
<td>Scooter, Moped</td>
<td>Motorbike</td>
<td>Suburban</td>
<td>Traffic Control</td>
<td>Electric Assistants</td>
</tr>
</tbody>
</table>

Select On-road Processes and relevant Pollutants

---

Select On-road Processes and relevant Pollutants
Pollutants and Processes: On Road Components

Select On-road Processes and relevant Pollutants

Select On-road Processes and relevant Pollutants
Pollutants and Processes: On Road Components

- Start Exhaust
- Extended Idle Exhaust
- Crankcase Start Exhaust
- Crankcase Extended Idle Exhaust
General Output

Output Emissions Detail
Output Emissions Detail

- If the Emission Rates option is selected on the Scale panel, EPA states that output by Source Use Type, Model Year, or Fuel Type should likewise not be selected.

Enter Project Data Manager

Select from Drop-Down Menu or . . .

. . . Click Enter/Edit Data
MOVES Project Data Manager

Database tab functions:
- Refresh
- Create Database
- Clear All Imported Data

Specifying Project Data

<table>
<thead>
<tr>
<th>Data Manager Tab</th>
<th>Project</th>
<th>County</th>
<th>Importer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Links</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Link Source Types</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Link Drive Schedules</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Off-Network</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operating Mode Distribution</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age Distribution</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Fuel</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Meteorology Data</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Hoteling</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
Specifying Project Data

<table>
<thead>
<tr>
<th>Data Manager Tab</th>
<th>Project</th>
<th>County</th>
<th>Importer</th>
</tr>
</thead>
<tbody>
<tr>
<td>I/M Programs</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Retrofit Data</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Generic</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Average Speed Distribution</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Ramp Fraction</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Road Type Distribution</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Source Type Population</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>Starts</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Vehicle Type VMT</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
</tbody>
</table>

Defining Links

- Highway segments of collective traffic activity, emission conditions, and highway configuration
- Define a distinct link whenever a change in traffic, emissions, and/or highway configuration occurs
- Traffic
  - Volume
  - Speed
  - Truck percentage
Defining Links

- Emissions
  - Traffic
  - Road type (drive schedule)
  - Road grade
- Highway configuration
  - Traffic and emissions
  - Width
  - Directional orientation or bearing

Characterizing Project Emissions

- Link Average Vehicle Speed
  - Default drive cycles
- Link Drive Schedules*
  - User-defined drive cycles representing the fleet average
- Operating Mode (OpMode) Distribution*
  - User-defined drive cycles by individual source type
- *Advanced Applications
  - Modal emission rates
  - Operating mode look-up tables
Phoenix, Arizona

February 17 - 20, 2015

MOVES Project Data Manager

Common tab functions:
- Browse...
- Create Template...
- Clear Imported Data
- Import
- Export Imported Data

Alternate tab functions:
- Export Most Recent Execution Data
- Export Default Data

Links Template
## Default Drive Schedules

<table>
<thead>
<tr>
<th>ID</th>
<th>Average Speed (mph)</th>
<th>Drive Schedule Name</th>
<th>ID</th>
<th>Average Speed (mph)</th>
<th>Drive Schedule Name</th>
<th>ID</th>
<th>Average Speed (mph)</th>
<th>Drive Schedule Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>199</td>
<td>34.6</td>
<td>LD Freeway Ramp</td>
<td>304</td>
<td>19.4</td>
<td>HD 20mph Non-Freeway</td>
<td>1009</td>
<td>73.7991</td>
<td>Final FC01 LOS AF Cycle</td>
</tr>
<tr>
<td>201</td>
<td>4.6</td>
<td>MD 5mph Non-Freeway</td>
<td>305</td>
<td>25.6</td>
<td>HD 25mph Non-Freeway</td>
<td>1017</td>
<td>66.3632</td>
<td>Final FC11 LOS B Cycle</td>
</tr>
<tr>
<td>202</td>
<td>10.7</td>
<td>MD 10mph Non-Freeway</td>
<td>306</td>
<td>32.5</td>
<td>HD 30mph Non-Freeway</td>
<td>1018</td>
<td>64.3993</td>
<td>Final FC11 LOS C Cycle</td>
</tr>
<tr>
<td>203</td>
<td>15.6</td>
<td>MD 15mph Non-Freeway</td>
<td>351</td>
<td>34.3</td>
<td>HD 30mph Freeway</td>
<td>1019</td>
<td>58.7949</td>
<td>Final FC11 LOS D Cycle</td>
</tr>
<tr>
<td>204</td>
<td>20.8</td>
<td>MD 20mph Non-Freeway</td>
<td>352</td>
<td>47.1</td>
<td>HD 40mph Freeway</td>
<td>1020</td>
<td>46.132</td>
<td>Final FC11 LOS E Cycle</td>
</tr>
<tr>
<td>205</td>
<td>24.5</td>
<td>MD 25mph Non-Freeway</td>
<td>353</td>
<td>54.2</td>
<td>HD 50mph Freeway</td>
<td>1021</td>
<td>20.6006</td>
<td>Final FC11 LOS F Cycle</td>
</tr>
<tr>
<td>206</td>
<td>31.5</td>
<td>MD 30mph Non-Freeway</td>
<td>354</td>
<td>59.4</td>
<td>HD 60mph Freeway</td>
<td>1033</td>
<td>8.71909</td>
<td>Final FC14 LOS F Cycle</td>
</tr>
<tr>
<td>251</td>
<td>34.4</td>
<td>MD 30mph Freeway</td>
<td>355</td>
<td>71.7</td>
<td>HD High Speed Freeway</td>
<td>1043</td>
<td>15.733</td>
<td>Final FC19 LOS AC Cycle</td>
</tr>
<tr>
<td>252</td>
<td>44.5</td>
<td>MD 40mph Freeway</td>
<td>399</td>
<td>25.3</td>
<td>HD Freeway Ramp</td>
<td>1011</td>
<td>49.0722</td>
<td>Final FC02 LOS DF Cycle</td>
</tr>
<tr>
<td>253</td>
<td>55.4</td>
<td>MD 50mph Freeway</td>
<td>401</td>
<td>15</td>
<td>Bus Low Speed Urban</td>
<td>1029</td>
<td>31.0232</td>
<td>Final FC14 LOS B Cycle</td>
</tr>
<tr>
<td>254</td>
<td>60.4</td>
<td>MD 60mph Freeway</td>
<td>402</td>
<td>30</td>
<td>Bus 30 mph Flow</td>
<td>1030</td>
<td>25.379</td>
<td>Final FC14 LOS C Cycle</td>
</tr>
<tr>
<td>255</td>
<td>72.8</td>
<td>MD High Speed Freeway</td>
<td>403</td>
<td>45</td>
<td>Bus 45 mph Flow</td>
<td>1041</td>
<td>18.5781</td>
<td>Final FC17 LOS D Cycle</td>
</tr>
<tr>
<td>299</td>
<td>31</td>
<td>MD Freeway Ramp</td>
<td>501</td>
<td>2.2</td>
<td>Refuse Truck Urban</td>
<td>1024</td>
<td>63.66</td>
<td>Final FC12 LOS C Cycle</td>
</tr>
<tr>
<td>301</td>
<td>5.8</td>
<td>HD 5mph Non-Freeway</td>
<td>101</td>
<td>2.5</td>
<td>LD Low Speed 1</td>
<td>1025</td>
<td>52.8263</td>
<td>Final FC12 LOS D Cycle</td>
</tr>
<tr>
<td>302</td>
<td>11.2</td>
<td>HD 10mph Non-Freeway</td>
<td>153</td>
<td>30.5</td>
<td>LD LOS E Freeway</td>
<td>1026</td>
<td>43.2662</td>
<td>Final FC12 LOS E Cycle</td>
</tr>
<tr>
<td>303</td>
<td>15.6</td>
<td>HD 15mph Non-Freeway</td>
<td>158</td>
<td>76</td>
<td>LD High Speed Freeway</td>
<td>3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

## Default Drive Schedules: Restricted Access

![Graph showing speed and time for High LOS and Low LOS scenarios](image)

---

30
Default Drive Schedules: Unrestricted Access

Link Drive Schedules Template
Link Drive Schedules – Modal Activity

- Link Drive Schedules – Emissions

*Idle emissions are a function of idle delay time. Highly congested LOS E (idle delay = 60 s) conditions are represented.
*Idle emissions are a function of idle delay time. Highly congested LOS E (idle delay = 60 s) conditions are represented.

**Spatial Differentiation**

Roadways can be segmented to differentiate modes of vehicle operation.
Operating Mode Distribution Template

Vehicle Specific Power (VSP)

\[ VSP = \frac{A v + B v^2 + C v^3 + m a v + m v g \sin \theta}{m_{\text{fixed}}} \]

Where

- \( A \) = rolling Term A,
- \( B \) = rolling Term B,
- \( C \) = drag Term C,
- \( v \) = average vehicle velocity (m/s),
- \( a \) = vehicle acceleration (m/s\(^2\)),
- \( m \) = source mass (metric tons),
- \( m_{\text{fixed}} \) = fixed mass factor (metric tons),
- \( g \) = gravitational constant, and
- \( \theta \) = road grade
Single Vehicle VSP Trajectories

Ranges of VSP Trajectories
Passenger Car OpMode Trajectories

![Graph showing passenger car VSP (kW/tonne) vs. distance (m) with different acceleration and braking scenarios.]

MOVES OpMode Bin Definitions

<table>
<thead>
<tr>
<th>Description</th>
<th>VSP (kW/tonne)</th>
<th>Speed (mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1 – 25</td>
<td>25 – 50</td>
</tr>
<tr>
<td>Cruise / Acceleration</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt; 30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>27 – 30</td>
<td></td>
<td></td>
</tr>
<tr>
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<tr>
<td>Coasting</td>
<td>&lt; 0</td>
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</table>
**MOVES OpMode Bin Definitions**

<table>
<thead>
<tr>
<th>Description</th>
<th>VSP (kW/tonne)</th>
<th>Speed (mph)</th>
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<tr>
<td></td>
<td></td>
<td>1 – 25</td>
</tr>
<tr>
<td>Braking</td>
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<td>25 – 50</td>
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<tr>
<td>Idling</td>
<td></td>
<td>≥ 50</td>
</tr>
<tr>
<td>Running</td>
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<tr>
<td>Tire Wear</td>
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</table>

SHO (Source Hours Operating) = Link Volume \times Travel Distance / Link Average Speed

**OpMode Emissions**

SHO (Source Hours Operating) = Link Volume \times Travel Distance / Link Average Speed
## OpMode Look-Up Table

<table>
<thead>
<tr>
<th>OpMode</th>
<th>2010 PM2.5 Exhaust Emissions (g/SHO) by Source Type</th>
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<tbody>
<tr>
<td></td>
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<td>13</td>
<td>0.2600</td>
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<td>14</td>
<td>0.3800</td>
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<td>22</td>
<td>0.1870</td>
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## OpMode Look-Up Table

<table>
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<tr>
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<th>2010 PM2.5 Exhaust Emissions (g/SHO) by Source Type</th>
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<td>25</td>
<td>0.6060</td>
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<td>27</td>
<td>0.8890</td>
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<td>29</td>
<td>13.5</td>
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<td>38.3</td>
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<td>33</td>
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<td>35</td>
<td>0.4340</td>
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<td>37</td>
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<td>38</td>
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<tr>
<td>39</td>
<td>2.60</td>
</tr>
<tr>
<td>40</td>
<td>2.84</td>
</tr>
</tbody>
</table>
Example Traffic Micro-Simulation Model Trajectories

Example MOVES Results for OpMode Distribution Versus Average Speed

Source: Lee, G., S. You, S. Ritchie, J. Saphores, and R. Jayakrishnan; Air Quality and Health Impacts of a Major Urban Freight Corridor; Research in Progress, University of California – Irvine; University of California Transportation Center; 2011.

Link Source Types Template
Typically, complete 16 unique MOVES runs to account for variability of PM emissions
- during the day (4 time periods)
  - morning peak – 6 am to 9 am
  - midday – 9 am to 4 pm
  - evening peak – 4 pm to 7 pm
  - overnight – 7 pm to 6 am
- and season (4 months)
  - January
  - April
  - July
  - October
Class Exercise: CO Speed Look-Up Table

• Divide into Teams
• Construct a speed look-up table of on-road, project scale CO emissions (in g/VMT) for an urban restricted roadway serving as a freight corridor during the morning peak hour traffic condition in Cobb County, Georgia for 2035
• Discuss the proposed methodology with respect to the MOVES navigation panels
  – Scale
  – Time spans
  – Geographic bounds
  – Pollutants and processes

Class Exercise: CO Speed Look-Up Table

• Using the Project Data Manager, specify project data by completing templates for
  – Links
  – Link source types
  – Meteorology
• Specify Links to represent vehicle speeds in 5 mph increments from 0 to 75 mph
  – Emissions for idling vehicles are obtained by specifying a vehicle speed of 0 mph
Class Exercise: CO Speed Look-Up Table

- Modify the available MPO data for Link Source Types for urban restricted access roadways to account for the large number of trucks expected to use the corridor
  - Supplied data file – MPO_LinkSourceTypes_UrbanRestrictedAccess.xls
  - % Trucks for project = 18%
    - Trucks = sourceTypeID 41, 42, 43, 51, 52, 53, 54, 61, and 62
    - Non-Trucks = sourceTypeID 11, 21, 31, and 32
- Export default Meteorology

Class Exercise: CO Speed Look-Up Table

- Use MPO supplied data for
  - Age distribution
  - Fuel
  - I/M programs
- Set-up the runspec; import project data; and run MOVES
- Post processing
  - Run MySQL script on output database
    - CO_Grams_Per_Veh_Mile.sql
- Review results in MySQL Workbench
Review Results in MySQL Workbench
SESSION 4: Highway Air Dispersion Modeling

Session Outline

• Need for Dispersion Modeling of Highway Projects
• Overview of the Environmental Protection Agency’s (EPA) Dispersion Models for Highway Applications
  – Spatial Regimes
  – Dispersion Model Characteristics
  – Dispersion Model Formulation
  – Summary of Input Data Requirements
  – Mechanics of Running the Models
  – Input / Output Files
Session Outline

• Recommendations for Streamlining the Modeling Process
  – Defining Links
  – Input File Templates
  – Technical Tools (Utility Programs)
  – Graphical User Interfaces
  – CO Categorical Finding
• Agency Experiences in Conducting Dispersion Modeling for Quantitative Hot-spot Analyses of Highway Projects in Particulate Matter (PM) Areas

Need for Dispersion Modeling of Highway Projects

• NEPA and Conformity Regulatory Requirements
  – Guideline for Modeling Carbon Monoxide from Roadway Intersections
  – Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas
Spatial Regimes

- **Project Scale / Microscale:**
  - Concentrations $> \pm 20\%$ for Distances $\leq 100$ m
- **Systems Scale / Mesoscale:**
  - Concentrations $< \pm 20\%$ for Distances between 100 m and 10,000 m
- **Regional Scale / Macroscale:**
  - Concentrations $< \pm 20\%$ for Distances $> 10,000$ m

**Project Scale**
Systems Level

Sunlight → Aloft Concentrations of Ozone and Precursors → Urban Plume

Anthropogenic NOx and VOC

Initial Concentrations (6 – 9 am) 1 hr 2 hr

Transport Time

Dispersion Model Characteristics

<table>
<thead>
<tr>
<th>Atmospheric Scale</th>
<th>Microscale (Project Scale)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure Scale</td>
<td>Mesoscale (Systems Scale)</td>
</tr>
<tr>
<td>Pollutant Applicability</td>
<td></td>
</tr>
<tr>
<td>Regulatory Applicability</td>
<td></td>
</tr>
<tr>
<td>Mathematical Class</td>
<td></td>
</tr>
<tr>
<td>Level of Sophistication</td>
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</tr>
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</table>
## Dispersion Model Characteristics

### Atmospheric Scale

<table>
<thead>
<tr>
<th>Exposure Scale</th>
<th>Pollutant Applicability</th>
<th>Regulatory Applicability</th>
<th>Mathematical Class</th>
<th>Level of Sophistication</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Acute (short-term, 1 to 24-hours)</strong></td>
<td>Inert pollutants, relatively unreactive in the microscale (CO, PM$<em>{10}$, PM$</em>{2.5}$, and NO$_2$)</td>
<td>Reactive pollutants in the mesoscale (O$_3$, NO$<em>2$, and PM$</em>{2.5}$)</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Chronic (long-term, annual)</strong></td>
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</tbody>
</table>

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### Dispersion Model Characteristics

<table>
<thead>
<tr>
<th>Atmospheric Scale</th>
<th>Exposure Scale</th>
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<td><strong>Chronic (long-term, annual)</strong></td>
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### Dispersion Model Characteristics

<table>
<thead>
<tr>
<th>Atmospheric Scale</th>
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<tr>
<td></td>
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<td>Regulatory Applicability</td>
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<tr>
<td></td>
<td></td>
<td>Highways with free-flow traffic</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Signalized intersections</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transportation terminals</td>
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<tr>
<td></td>
<td></td>
<td>Urban areas</td>
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<thead>
<tr>
<th>Mathematical Class</th>
<th>Level of Sophistication</th>
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<tr>
<td>Gaussian</td>
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<td>Statistical or Empirical</td>
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<tr>
<td>Physical</td>
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Dispersion Model Characteristics

Atmospheric Scale
Exposure Scale
Pollutant Applicability
Regulatory Applicability
Mathematical Class

<table>
<thead>
<tr>
<th>Level of Sophistication</th>
<th>Screening</th>
<th>Refined</th>
</tr>
</thead>
</table>

Model Characteristics for Highway Applications

- **CALINE3**
  - Atmospheric Scale: Microscale
  - Exposure Scale: Acute
  - Pollutant Applicability: Inert, relatively unreactive in the microscale, no secondary pollutant formation (CO)
  - Regulatory Applicability: Free-flow traffic
  - Model Class: Gaussian
  - Level of Sophistication: Refined
Model Characteristics for Highway Applications

• **CAL3QHC**
  - Atmospheric Scale: Microscale
  - Exposure Scale: Acute
  - Pollutant Applicability: Inert, relatively unreactive in the microscale, no secondary pollutant formation (CO)
  - Regulatory Applicability: Free-flow traffic and signalized intersections
  - Model Class: Gaussian
  - Level of Sophistication: Refined

Model Characteristics for Highway Applications

• **CAL3QHCR**
  - Atmospheric Scale: Microscale
  - Exposure Scale: Acute and chronic
  - Pollutant Applicability: Inert, relatively unreactive in the microscale, no secondary pollutant formation (CO, PM\textsubscript{10}, PM\textsubscript{2.5}, NO\textsubscript{2})
  - Regulatory Applicability: Free-flow traffic and signalized intersections
  - Model Class: Gaussian
  - Level of Sophistication: Refined
Model Characteristics for Highway Applications

• AERMOD
  ✓ Atmospheric Scale: Microscale
  ✓ Exposure Scale: Acute and chronic
  ✓ Pollutant Applicability: Inert, relatively unreactive in the microscale, no secondary pollutant formation (CO, PM$_{10}$, PM$_{2.5}$, NO$_2$)
  ✓ Regulatory Applicability: Free-flow traffic, signalized intersections, and transportation terminals
  ✓ Model Class: Gaussian
  ✓ Level of Sophistication: Refined

Model Characteristics for Highway Applications

• CMAQ – Community Multi-scale Air Quality
  ✓ Atmospheric Scale: Mesoscale
  ✓ Exposure Scale: Acute and chronic
  ✓ Pollutant Applicability: Inert and reactive, secondary pollutant formation (O$_3$, PM$_{2.5}$, and NO$_2$)
  ✓ Regulatory Applicability: Urban area
  ✓ Model Class: Numerical
  ✓ Level of Sophistication: Refined
Model Characteristics for Highway Applications

- **UAM – Urban Airshed Model**
  - Atmospheric Scale: Mesoscale
  - Exposure Scale: Acute and chronic
  - Pollutant Applicability: Inert (CO)
  - Regulatory Applicability: Urban area
  - Model Class: Numerical
  - Level of Sophistication: Refined

### Model Characteristics Table

<table>
<thead>
<tr>
<th>Model Characteristics</th>
<th>Atmospheric Scale</th>
<th>Project Scale Models</th>
<th>Systems Scale Models</th>
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<tr>
<td>Chronic</td>
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<tr>
<td>Free-flow Highways</td>
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<td>●</td>
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<tr>
<td>Signalized Intersections</td>
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<tr>
<td>Transportation Terminals</td>
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<td>Reactive Pollutants</td>
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</tbody>
</table>
www.epa.gov/ttn/scram/dispersionindex.htm

Technology Transfer Network
Support Center for Regulatory Atmospheric Modeling

Dispersion Modeling

Dispersion modeling uses mathematical techniques to characterize the atmospheric processes that disperse a pollutant emitted by a source. Based on emissions and meteorological data, dispersion models can be used to predict concentrations at selected receptor locations. These models are commonly used to determine compliance with National Ambient Air Quality Standards (NAAQS), and other regulatory requirements such as New Source Review (NSR) and Prevention of Significant Deterioration (PSD) permit applications. The model results are typically used to ensure that state and local regulatory requirements are not violated.

This page provides links to dispersion models and other related tools and information as follows:

**Preferred/Recommended Models:** A list of preferred models that are recommended in the ARB publication and are required to be used for regulatory modeling. These models are documented and referenced in the ARB publication and are recommended for regulatory modeling. The models on this page include the following:

AIRMOD Modeling System: A steady-state model that incorporates air dispersion and can be used to estimate the concentrations of air pollutants.

**Modeling Application Notes:** Notes and guidelines for the use of these models in regulatory applications.

**Specific Guidance:** Specific instructions for the use of these models in regulatory applications.

**Contact Information:** Contact information for the support center.

www.epa.gov/ttn/scram/dispersion_prefrec.htm

Technology Transfer Network
Support Center for Regulatory Atmospheric Modeling

Preferred/Recommended Models

These preferred dispersion models are listed in Appendix B of the ARB publication and are required to be used for regulatory modeling. These models are documented and referenced in the ARB publication and are recommended for regulatory modeling. The models on this page include the following:

AIRMOD Modeling System: A steady-state model that incorporates air dispersion and can be used to estimate the concentrations of air pollutants.

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www.epa.gov/ttn/scram/
dispersion_prefrec.htm#aermod

www.epa.gov/ttn/scram/
dispersion_prefrec.htm#caline3
www.epa.gov/ttn/scram/guidanceindex.htm

www.epa.gov/ttn/scram/guidance_permit.htm
www.epa.gov/ttn/scram/guidance_permit.htm

www.epa.gov/ttn/scram/guidance_sip.htm

Technology Transfer Network Support Center for Regulatory Atmospheric Modeling

State Implementation Plan (SIP) Attainment Demonstration Guidance

The EPA’s Acid Rain Modeling Tools (ART) series provides guidance documents to assess and protect public health and ecosystems from acid rain and to help states demonstrate attainment of the National Ambient Air Quality Standards (NAAQS) for the NAAQS exceedances. This guidance documents are a product of modeling applications to demonstrate air quality exceedances but are also useful for modeling no-ambiance areas to support action in areas of the Total Acid Deposition Reduction (TADR). They also help in determining the need for air quality standards for the protection of public health and ecosystems. This section of guidance is divided into three components:

- State Implementation Plan (SIP) Attainment Demonstration Guidance
- Air Quality Modeling Tools (AQMT) Guidance
- Air Quality Management Modeling Guidance

Supporting Documents - Ozone/NOx/Regional

Draft Criteria for Assessing Whether an Emission Reduction Area is Affected by Cross-State Transport (2007), PDF - The Cross-State Transport (CST) Guidance documents are available on the EPA's website. These documents provide guidance on the methodology for assessing whether an area is affected by cross-state transport of emissions. The CST criteria are used to determine whether an area is included in a Regional Haze Air Quality Study (RH-AQS) or if it is a nonattainment area. These criteria are important for states to determine their obligations under the Clean Air Act. For more information, visit the EPA’s regional haze program website.
Dispersion Model Formulation

Meteorology
- Wind Speed
- Wind Direction
- Atmospheric Stability
- Mixing Height

Emissions
- Highway Configuration
- Traffic Parameters
- Emission Factors

Air Dispersion Model
- Transport
- Diffusion
- Chemical Transformation

Receptor Concentration
Dispersion Model Formulation

- Steady-state Gaussian Dispersion
  - Emission rate, wind speed, wind direction, and atmospheric stability are constant during the life of the plume.
  - Concentrations are assumed to follow a Gaussian distribution in the cross-wind horizontal and vertical directions.
  - Assumes dispersion along the transport wind direction has a small effect on the plume.
  - Computationally simple.

Basics of the Gaussian Plume Equation

$$\chi_{\text{avg}} = \frac{Q}{u \times A}$$

where $\chi_{\text{avg}}$ is the average pollutant concentration in the plume cross-section (g/m$^3$);

$Q$ is the pollutant emission rate (g/s);

$u$ is the transport wind speed (m/s); and

$A$ is the plume cross-sectional area.
Basics of the Gaussian Plume Equation

\[
g/m^3 \Delta \frac{g/s}{m/s \times m^2}
\]

\[
\chi_{avg} = \frac{Q}{u \times \pi r_y r_z}
\]

where \( r_y \) is the horizontal radius of the plume (m) and \( r_z \) is the vertical radius of the plume (m).

The Gaussian or normal distribution can be expressed mathematically:

\[
f(v) = \frac{1}{\sqrt{2\pi} \sigma} \left\{ \exp \left[ -\frac{1}{2} \left( \frac{v - \mu}{\sigma} \right)^2 \right] \right\}
\]
The Gaussian Plume Equation

\[ \chi = \frac{Q}{2\pi u \sigma_y \sigma_z} \exp \left\{ -\frac{1}{2} \left( \frac{y}{\sigma_y} \right)^2 \right\} \left\{ \exp \left( -\frac{1}{2} \left( \frac{z-H}{\sigma_z} \right)^2 \right) + \exp \left( -\frac{1}{2} \left( \frac{z+H}{\sigma_z} \right)^2 \right) \right\} \]

Dilution Term  Crosswind Term  Vertical Term  Reflection Term

What is the form of this equation for:
- ground-level concentrations (z = 0)
- on plume centerline (y = 0)
- due to a ground-level source (H = 0)?

HINT: \( \exp(0) = ? \)

Basics of the Gaussian Plume Equation

\[ \chi = \frac{Q}{\pi u \sigma_y \sigma_z} \]

\[ \chi = \frac{Q}{\pi u r_y r_z} \]
Horizontal Dispersion Coefficients – $\sigma_y$

adapted from Slade, 1968

Vertical Dispersion Coefficients – $\sigma_z$

adapted from Slade, 1968
Plume Dispersion from Highways – CAL3 Series

adapted from Benson, 1979

Plume Dispersion from Highways – Uniform Mixing Zone (CAL3 Series)

adapted from Benson, 1979
Vertical Dispersion Parameter – CAL3 Series

adapted from Benson, 1979

\[ \sigma_z = A \]  

\[ Z_0 = \text{AERODYNAMIC ROUGHNESS} \]  

\[ \text{ATIM} = \text{AVERAGING TIME} \]  

\[ \text{TR} = \text{MIXING ZONE RESIDENCE TIME} \]  

\[ x = \text{PLUME CENTERLINE AXIS} \]  

\[ \sigma_z = \text{VERTICAL DISPERSION PARAMETER} \]

Surface Roughness for Various Land Uses

adapted from Benson, 1979

<table>
<thead>
<tr>
<th>Type of Surface</th>
<th>( z_0 ) (cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smooth mud flats</td>
<td>0.001</td>
</tr>
<tr>
<td>Tarmac (pavement)</td>
<td>0.002</td>
</tr>
<tr>
<td>Dry lake bed</td>
<td>0.003</td>
</tr>
<tr>
<td>Smooth desert</td>
<td>0.03</td>
</tr>
<tr>
<td>Grass (5-6 cm)</td>
<td>0.75</td>
</tr>
<tr>
<td>Grass (4 cm)</td>
<td>0.14</td>
</tr>
<tr>
<td>Alfalfa (15.2 cm)</td>
<td>2.72</td>
</tr>
<tr>
<td>Grass (60-70 cm)</td>
<td>11.4</td>
</tr>
<tr>
<td>Wheat (60 cm)</td>
<td>22</td>
</tr>
<tr>
<td>Corn (220 cm)</td>
<td>74</td>
</tr>
<tr>
<td>Citrus orchard</td>
<td>198</td>
</tr>
<tr>
<td>Fir forest</td>
<td>283</td>
</tr>
<tr>
<td>City land use</td>
<td></td>
</tr>
<tr>
<td>Single family residential</td>
<td>108</td>
</tr>
<tr>
<td>Apartment residential</td>
<td>370</td>
</tr>
<tr>
<td>Office</td>
<td>175</td>
</tr>
<tr>
<td>Central Business District</td>
<td>321</td>
</tr>
<tr>
<td>Park</td>
<td>127</td>
</tr>
</tbody>
</table>
Atmospheric Stability

from Slade, 1968

## Pasquill’s Stability Categories

adapted from Slade, 1968

<table>
<thead>
<tr>
<th>Surface Wind Speed (m/s)</th>
<th>Daytime Insolation</th>
<th>Nighttime Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strong</td>
<td>Moderate</td>
</tr>
<tr>
<td>&lt; 2</td>
<td>A</td>
<td>A-B</td>
</tr>
<tr>
<td>2</td>
<td>A-B</td>
<td>B</td>
</tr>
<tr>
<td>4</td>
<td>B</td>
<td>B-C</td>
</tr>
<tr>
<td>6</td>
<td>C</td>
<td>C-D</td>
</tr>
<tr>
<td>&gt; 6</td>
<td>C</td>
<td>D</td>
</tr>
<tr>
<td>A: Extremely unstable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B: Moderately unstable</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C: Slightly unstable</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A: Extremely unstable  
B: Moderately unstable  
C: Slightly unstable
D: Neutral
E: Slightly stable
F: Moderately stable
Notes on Pasquill’s Stability Categories

- Night – 1 hour before sunset to 1 hour after sunrise
- D stability should be used (regardless of wind speed) for:
  - overcast conditions during day or night and
  - any sky condition during the hour preceding or following night

Monin-Obukhov Length

- AERMOD provides for a continuous measure of atmospheric stability and dispersion based on the Obukhov length (L)
- Also known as the Monin-Obukhov length, L is used to describe the effects of buoyancy on turbulent flows in the planetary boundary layer
  - L < 0 indicates unstable conditions
  - L = 0 indicates neutral conditions
  - L > 0 indicates stable conditions
Characterizing Atmospheric Stability

<table>
<thead>
<tr>
<th>Stability Class</th>
<th>L (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>-6.9</td>
</tr>
<tr>
<td>B</td>
<td>-42.6</td>
</tr>
<tr>
<td>C</td>
<td>-200.5</td>
</tr>
<tr>
<td>D</td>
<td>-8888</td>
</tr>
<tr>
<td>E</td>
<td>159.3</td>
</tr>
<tr>
<td>F</td>
<td>35.4</td>
</tr>
</tbody>
</table>

Based on Golder (1972) as implemented in EPA's AERMOD, CALPUFF, and CTDMPplus models

Mixing Height

adapted from Beaton, 1972
Link / Receptor Configuration – CAL3 Series

- XL1, YL1 = Link centerline start
- XL2, YL2 = Link centerline end
- XR, YR = Receptor
- WL = Mixing zone width

Link / Receptor Configuration – AERMOD Line

- Xs1, Ys1 = Line midpoint start
- Xs2, Ys2 = Line midpoint end
- Xcoord, Ycoord = Receptor
- W = Highway width
Link / Receptor Configuration – AERMOD Area

- $X_s, Y_s =$ Area source vertex
- $X_{coord}, Y_{coord} =$ Discrete receptor
- $X_{init} =$ Length of $X$ side of area
- $Y_{init} =$ Length of $Y$ side of area
- $\text{Angle} =$ Orientation angle from north

Link / Receptor Configuration – AERMOD Volume

- $X_s, Y_s =$ Volume source center
- $X_{coord}, Y_{coord} =$ Discrete receptor
- $W =$ Highway width
  (volume source spacing = $W$)
- $S_{y_{init}} =$ Initial lateral dimension
  of volume source ($W / 2.15$)
<table>
<thead>
<tr>
<th>Program Controls</th>
<th>Run options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receptor Location</td>
<td>Output options</td>
</tr>
<tr>
<td>Highway Configuration</td>
<td></td>
</tr>
<tr>
<td>Emissions</td>
<td></td>
</tr>
<tr>
<td>Meteorology</td>
<td></td>
</tr>
</tbody>
</table>

Summary on Input Data Requirements

Program Controls

- Receptor Location
- Highway Configuration
- Emissions
- Meteorology

<table>
<thead>
<tr>
<th>Receptor Location</th>
<th>X and Y location coordinates</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Height of the breathing zone (Z)</td>
</tr>
</tbody>
</table>

Summary on Input Data Requirements
### Summary on Input Data Requirements

**Program Controls**

**Receptor Location**

**Highway Configuration**
- Source coordinates
- Source height
- Source width

**Emissions**
- Traffic volume
- Emission factor or rate

**Meteorology**
Summary on Input Data Requirements

Program Controls
Receptor Location
Highway Configuration
Emissions

Meteorology

Basic parameters:
- Wind speed
- Wind direction
- Atmospheric stability measure
- Mixing height

MPRM Met Data – CAL3QHCR Input Requirements

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Day</th>
<th>Hour</th>
<th>Bearing</th>
<th>U</th>
<th>Temp</th>
<th>Class</th>
<th>Zrur</th>
<th>Zurb</th>
</tr>
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<tbody>
<tr>
<td>12</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>278.1</td>
<td>7</td>
<td>15</td>
<td>400</td>
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<tr>
<td>12</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>305</td>
<td>2.03</td>
<td>278.8</td>
<td>6</td>
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<td>7</td>
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<td>400</td>
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<td>12</td>
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<td>1</td>
<td>4</td>
<td>297</td>
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<td>263</td>
<td>1.21</td>
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<td>0</td>
<td>275.4</td>
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<td>18</td>
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<td>1.25</td>
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<td>92</td>
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<td>0</td>
<td>0</td>
<td>282.5</td>
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</table>
### AERMET Surface Data

<table>
<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Day</th>
<th>Jday</th>
<th>Hour</th>
<th>U</th>
<th>W</th>
<th>VPTG</th>
<th>Zec</th>
<th>Zim</th>
<th>L</th>
<th>Z0</th>
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<td>-999</td>
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<td>6.5</td>
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<td>1</td>
<td>1</td>
<td>3</td>
<td>-2</td>
<td>0.044</td>
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<td>-999</td>
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<td>3.8</td>
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<td>-1.6</td>
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<td>8</td>
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<td>0.039</td>
<td>-9</td>
<td>-999</td>
<td>18</td>
<td>3.5</td>
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<td>0.012</td>
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</tbody>
</table>

### Mechanics of Running the Models

- EPA distributed versions of the models
- Tips for managing files
- Run the models
- Input file structures
- Constructing input files
- Output file structures
EPA Distributed Versions of the Models

- CALINE3 (Dated 12317) files in caline3_32.zip
  - CALINE3.FOR – Fortran source code
  - CALINE3_32.EXE – Executable program
  - CALINE3.EXP – Input file for the test case
  - CALINE3.LST – Output file for the test case
  - CALINE3_32.RME – Readme file

EPA Distributed Versions of the Models

- CAL3QHC (Dated 04244) files in cal3qhc.zip
  - CAL3QHC.FOR – Fortran source code
  - CAL3QHC.EXE – Executable program
  - EX1.BAT, EX2.BAT, EX3.BAT, EXP.BAT – Batch files for executing the test cases
  - EX-1.DAT, EX-2.DAT, EX-3.DAT, EX-P.DAT – Input data files for the test cases
  - EX-1.OUT, EX-2.OUT, EX-3.OUT, EX-P.OUT – Output files for the test cases
EPA Distributed Versions of the Models

• CAL3QHC (Dated 04244) files in cal3qh.zip
  - FC1.BAT, FC2.BAT, FC3.BAT, FCP.BAT – Batch files for comparing user results with test case results
  - READMEHC.TXT – Readme file

EPA Distributed Versions of the Models

• CAL3QHCR (Dated 13196) files in cal3qhcr_13196.zip
  - CAL3QHCR.FOR – Fortran source code
  - CAL3QHCR.EXE – Executable program
  - C1C.BAT, Med.BAT, R1C.BAT, R1P.BAT, R2C.BAT, R2P.BAT – Batch files for executing the test cases
  - C1C.INP, Med.INP, R1C.INP, R1P.INP, R2C.INP, R2P.INP – Input data files for the test cases
  - C1C.OUT, Med.OUT, R1C.OUT, R1P.OUT, R2C.OUT, R2P.OUT – Output files for the test cases
EPA Distributed Versions of the Models

• CAL3QHCR (Dated 13196) files in cal3qhcr_13196.zip
  – FCC1C.BAT, FCMed.BAT, FCR1C.BAT, FCR1P.BAT, FCR2C.BAT, FCR2P.BAT – Batch files for comparing user results with test case results
  – READMEHC.TXT – Readme file
  – C1C.CTL, Med.CTL, R1C.CTL, R1P.CTL, R2C.CTL, R2P.CTL – Control files with a list of input and output filenames read by the program

EPA Distributed Versions of the Models

• CAL3QHCR (Dated 13196) files in cal3qhcr_13196.zip
  – C1C.MSG, Med.MSG, R1C.MSG, R1P.MSG, R2C.MSG, R2P.MSG – Files containing error and other messages
  – C1C.ET1, Med.ET1, R1C.ET1, R1P.ET1, R2C.ET1, R2P.ET1 – copy of vehicular emissions, traffic volume, and signalization (ETS) data as read from the input control file
  – C1C.ET2, Med.ET2, R1C.ET2, R1P.ET2, R2C.ET2, R2P.ET2 – preprocessed *.ET1 data
  – C1C.ILK, Med.ILK, R1C.ILK, R1P.ILK, R2C.ILK, R2P.ILK – link data output files
EPA Distributed Versions of the Models

• CAL3QHCR (Dated 13196) files in cal3qhcr_13196.zip
  – C1C.DIF, Med.DIF, R1C.DIF, R1P.DIF, R2C.DIF, R2P.DIF – link data output files
  – C1C.PLT, Med.PLT, R1C.PLT, R1P.PLT, R2C.PLT, R2P.PLT – link data output files
  – PIT-64.MET, S2422590.ASC, TC1.MET – processed meteorological data files
  – readmeR.txt – Readme file

EPA Distributed Versions of the Models

• AERMOD (Dated 14134) in aermod_exe.zip
  – aermod.exe – Executable program
  – aermod_readme – Readme file

• AERMOD (Dated 14134) in aermod_source.zip
  – Fortran source code
    • aermod.for evset.for ouset.for setup.for
    • calc1.for iblval.for output.for siggrid.for
    • calc2.for inpsum.for pitarea.for sigmas.for
    • coset.for meset.for prime.for soset.for
    • evcalc.for metext.for prise.for tempgrid.for
    • evoutput.for modules.for reset.for windgrid.for
Tips for Managing Files

- Use a descriptive root filename, e.g., Build_AltA_2017, NoBuild_2017, etc.
  - *.inp – input data file
  - *.met – input meteorological data file
  - *.out – descriptive output file
  - *.pst – postfile output of hourly concentrations at each receptor for post-processing
  - *.plt – plotfile output of design value concentrations at each receptor for plotting
  - *.bat – batch file for executing DOS commands to run a model

Run the Models

- Step 1 – Create an input file, *.inp
  - Use a text editor
    - Like Notepad, supplied with Windows®
  - Use a word processor
    - Caution: be sure to use the “Save As” command to save as a Plain Text file
  - Use Microsoft Excel®
    - Caution: be sure “Save As” as a CSV (Comma Delimited file) – requires subsequent editing
  - Use a free commercial text editor
    - NoteTab Light, Notepad++, Programmer’s Notepad, or TotalEdit
Run the Models

• Step 2 – Save the input file with a descriptive name
  – e.g., Build_AltA_2017.inp, NoBuild_2017.inp, etc.

• Step 3 – Copy the input file saved in Step 2 to the model default input filename
  – For AERMOD, AERMOD.inp
  – For CAL3QHCRi, CAL3QHCR.inp
  – For CAL3QHCi, CAL3QHC.inp
  – For CALINE3i, CALINE3.inp

Run the Models

• Step 4 – Execute the model
  – Option 1 – using Windows Explorer
    • Right-click the Windows Start Icon
    • Select Open Windows Explorer
    • Navigate to the “Project” folder containing the input file, met data file (for AERMOD and CAL3QHCRi), and model executable
    • Double-click on the model application *.exe file
Run the Models

• Step 4 – Execute the model
  – Option 2 – using a command prompt Window
    • Click the Windows Start Icon
    • Select All Programs
    • Select Accessories
    • Select Command Prompt
    • Navigate to the “Project” folder containing the input file, met data file (for AERMOD and CAL3QHCRi), and model executable
    • Type the model name and hit enter, i.e.,
      AERMOD, CAL3QHCRi, CAL3QHCl, or CALINE3i

Run the Models

• Some useful DOS commands for navigation:
  – C:\> Example command prompt
  – C:\> d: Navigate to drive D:
  – D:\> cd Change directories
  – D:\> dir Obtain directory (list)
  – D:\> dir /w Obtain directory (wide list)
  – D:\> cls Clear screen
Run the Models

- In-class Demonstration

Input File Structure – AERMOD

- An AERMOD input file is divided into 5 functional pathways applicable to PM hot-spot analyses for specifying data:
  - CO – Control options
  - SO – Source data
  - RE – Receptor data
  - ME – Meteorology data
  - OU – Output options
Input File Structure – AERMOD

- Each line or data record in the input file consists of:
  - One of the 2-character pathway IDs in columns 1 and 2
  - One blank space in column 3
  - An 8-character keyword in columns 4 through 11
  - One blank space in column 12
  - A parameter list (data values) in columns 13 through 132, as necessary
    - Continue additional required data values on the next line
  - Example
    
    SO EMISFACT NBFwy1 SEASHR 6*2.9E-07 3*6.7E-07 7*2.5E-07 3*5.6E-07 5*2.9E-07
    SO EMISFACT NBFwy1 SEASHR 6*2.0E-07 3*4.6E-07 7*1.7E-07 3*3.6E-07 5*2.0E-07
    SO EMISFACT NBFwy1 SEASHR 6*1.5E-07 3*3.4E-07 7*1.4E-07 3*3.1E-07 5*1.5E-07
    SO EMISFACT NBFwy1 SEASHR 6*1.9E-07 3*4.3E-07 7*1.6E-07 3*3.6E-07 5*1.9E-07

Input File Structure – AERMOD

- Use only 1 space between the pathway ID and keyword
- Any number of spaces can separate the keyword and data values in the parameter list
- Do not use the tab key
- End the line after the last data value using the enter key with no extra spaces
- The order of data values is important
Input File Structure – AERMOD

- First line of each pathway uses the STARTING keyword
- Last line of each pathway uses the FINISHED keyword
- Blank lines and comment lines can be effectively used to document the data file
  - Blank lines can be used to separate pathways, sources, etc.
  - Comment lines start with ** as the first two characters on a line and can be used to document information and as column headings to label input data values
- All input data values are in metric units

CO Pathway Mandatory Keywords – AERMOD

<table>
<thead>
<tr>
<th>Keyword</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STARTING</td>
<td>Indicates the beginning of inputs for the pathway; this keyword mandatory on each of the pathways</td>
</tr>
<tr>
<td>TITLEONE</td>
<td>A user-specified title line (up to 68 characters) that will appear each page of the printed output file (an optional second title line also available with the keyword TITLE TWO)</td>
</tr>
<tr>
<td>MODELOPT</td>
<td>Controls the modeling options selected for a particular run through series of secondary keywords</td>
</tr>
<tr>
<td>AVERAGE</td>
<td>Identifies the averaging periods to be calculated for a particular run</td>
</tr>
<tr>
<td>POLLUTID</td>
<td>Identifies the type of pollutant being modeled. At the present time, this option has no influence on the results</td>
</tr>
<tr>
<td>RUNORNOT</td>
<td>A special keyword that tells the model whether to run the full model executions or not. If the user selects not to run, then the runstream setup file will be processed and any input errors reported, but no dispersion calculations will be made</td>
</tr>
<tr>
<td>FINISHED</td>
<td>Indicates that the user is finished with the inputs for this pathway; this keyword is also mandatory on each of the other pathways</td>
</tr>
</tbody>
</table>
### SO Pathway Mandatory Keywords – AERMOD

<table>
<thead>
<tr>
<th>Keyword</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STARTING</td>
<td></td>
</tr>
<tr>
<td>LOCATION</td>
<td>Identifies a particular source ID and specifies the source type and location of that source</td>
</tr>
<tr>
<td>SRCPARAM</td>
<td>Specifies the source parameters for a particular source ID identified by a previous LOCATION card</td>
</tr>
<tr>
<td>SRCGROUP</td>
<td>Specifies how sources will be grouped for calculation purposes. There is always at least one group, even though it may be the group of ALL sources and even if there is only one source</td>
</tr>
<tr>
<td>FINISHED</td>
<td></td>
</tr>
</tbody>
</table>

### RE Pathway Mandatory* Keywords – AERMOD

<table>
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<th>Description</th>
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<tbody>
<tr>
<td>STARTING</td>
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</tr>
<tr>
<td>GRIDCART</td>
<td>Defines a Cartesian grid receptor network</td>
</tr>
<tr>
<td>GRIDPOLR</td>
<td>Defines a polar grid receptor network</td>
</tr>
<tr>
<td>DISCCART</td>
<td>Defines the discretely placed receptor locations referenced to a Cartesian system</td>
</tr>
<tr>
<td>DISCPOLR</td>
<td>Defines the discretely placed receptor locations referenced to a polar system</td>
</tr>
<tr>
<td>FINISHED</td>
<td></td>
</tr>
</tbody>
</table>

*At least one of the Receptor pathway keywords must be present
ME Pathway Mandatory Keywords – AERMOD

<table>
<thead>
<tr>
<th>Keyword</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STARTING</td>
<td></td>
</tr>
<tr>
<td>SURFFILE</td>
<td>SURFFILE - Specifies the filename and format for the input surface meteorological data file</td>
</tr>
<tr>
<td>PROFFILE</td>
<td>Specifies the filename and format for the input profile meteorological data file</td>
</tr>
<tr>
<td>SURFDATA</td>
<td>Specifies information about the surface meteorological data which will be used in the modeling</td>
</tr>
<tr>
<td>UAIRDATA</td>
<td>Specifies information about the upper air meteorological data which will be used in the modeling</td>
</tr>
<tr>
<td>PROFBASE</td>
<td>Specifies the base elevation above MSL for the potential temperature profile</td>
</tr>
<tr>
<td>FINISHED</td>
<td></td>
</tr>
</tbody>
</table>

OU Pathway Mandatory* Keywords – AERMOD

<table>
<thead>
<tr>
<th>Keyword</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>STARTING</td>
<td></td>
</tr>
<tr>
<td>RECTABLE</td>
<td>Specifies the selection of high value by receptor table output options</td>
</tr>
<tr>
<td>MAXTABLE</td>
<td>Specifies the selection of overall maximum value table output options</td>
</tr>
<tr>
<td>DAYTABLE</td>
<td>Specifies the selection of printed results (by receptor) for each day of data processed (this option can produce very large files and such be used with care)</td>
</tr>
<tr>
<td>FINISHED</td>
<td></td>
</tr>
</tbody>
</table>

*All of the keywords on the Output pathway are optional, although the model will warn the user if no printed outputs are requested and will halt processing if no outputs (printed results or file outputs) are selected.
### Constructing an Input File – AERMOD

**CO STARTING**

<table>
<thead>
<tr>
<th>TITLE ONE</th>
<th>AERMOD Class Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>TITLE TWO</td>
<td>2008-2012 Meteorology</td>
</tr>
</tbody>
</table>

**MODELOPT** FLAT CONC

<table>
<thead>
<tr>
<th>AVERAGE</th>
<th>24 ANNUAL</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>URBANOPT</th>
<th>2000000</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>POLLUTID</th>
<th>PM2.5</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>FLAGPOLE</th>
<th>1.5</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>RUNORNOT</th>
<th>RUN</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>ERRORFILE</th>
<th>ERRORS.OUT</th>
</tr>
</thead>
</table>

**CO FINISHED**

### Constructing an Input File – AERMOD

**SO STARTING**

**Xs1 Ys1 Xs2 Ys2**

<table>
<thead>
<tr>
<th>Scrid</th>
<th>Srtyp</th>
<th>Xs1</th>
<th>Ys1</th>
<th>Xs2</th>
<th>Ys2</th>
</tr>
</thead>
<tbody>
<tr>
<td>------</td>
<td>------</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
</tbody>
</table>

**LOCATION**

<table>
<thead>
<tr>
<th>NB_Fwy_1</th>
<th>LINE</th>
<th>600.9</th>
<th>-88.1</th>
<th>450.7</th>
<th>198.5</th>
</tr>
</thead>
</table>

**Line Source**

<table>
<thead>
<tr>
<th>Nb_fwy_1</th>
<th>Lnen</th>
<th>Relhgt</th>
<th>Wdth</th>
<th>Sznit</th>
</tr>
</thead>
</table>

**Parameters:**

<table>
<thead>
<tr>
<th>Qflag</th>
<th>ON</th>
<th>AM</th>
<th>MD</th>
<th>PM</th>
<th>ON</th>
</tr>
</thead>
</table>

**SRCPARAM**

<table>
<thead>
<tr>
<th>NB_Fwy_1</th>
<th>1.0</th>
<th>1.3</th>
<th>14.63</th>
<th>1.2</th>
</tr>
</thead>
</table>

**Variable Qflag**

<table>
<thead>
<tr>
<th>Nb_fwy_1</th>
<th>SEASHR</th>
<th>6*2.9E-07</th>
<th>3*6.7E-07</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nb_fwy_1</td>
<td>SEASHR</td>
<td>6*2.0E-07</td>
<td>3*4.6E-07</td>
</tr>
<tr>
<td>Nb_fwy_1</td>
<td>SEASHR</td>
<td>6*1.5E-07</td>
<td>3*3.4E-07</td>
</tr>
<tr>
<td>Nb_fwy_1</td>
<td>SEASHR</td>
<td>6*1.9E-07</td>
<td>3*4.3E-07</td>
</tr>
</tbody>
</table>

88
Constructing an Input File – AERMOD

URBANSRC ALL
SRCGROUP ALL
SO FINISHED

Determining AERMOD Emission Rate for Area and Line Sources

• Typically, complete 16 unique MOVES runs to account for variability of PM emissions
  – during the day (4 time periods)
    • morning peak – 6 am to 9 am
    • midday – 9 am to 4 pm
    • evening peak – 4 pm to 7 pm
    • overnight – 7 pm to 6 am
  – and during each season (4 months)
    • January
    • April
    • July
    • October
Determining AERMOD Emission Rate for Area and Line Sources

- Obtain emission results in grams per hour using the MOVES Inventory Calculation Type
- Convert emissions in grams per hour to grams per second
- Divide emissions in grams per second by the link length and the link width to obtain emissions in grams per second per square meters

EPA Guidance on Determining Release Height

- May be estimated from the midpoint of the initial vertical dimension
  - For moving light-duty vehicles, this is about 1.3 meters
  - For moving heavy-duty vehicles, it is 3.4 meters
- Release height of mixed fleets may be estimated using an emissions-weighted or volume-weighted average
  - Emissions-weighted average – for a 40%/60% light-duty/heavy-duty emissions share, the source release height would be
    \[(0.4 \times 1.3) + (0.6 \times 3.4) = 2.6\] meters
  - Or could be based on traffic volumes, i.e., light-duty/ heavy-duty vehicle fractions
EPA Guidance on Determining Initial Vertical Dispersion Coefficient (Szinit)

• Assume the initial vertical dimension is about 1.7 times the average vehicle height to account for the effects of vehicle-induced turbulence
  – For light-duty vehicles, about 2.6 meters
  – For heavy-duty vehicles, about 6.8 meters
• For mixed fleets, base estimates on an emissions-weighted or volume-weighted average
  – For example, if light-duty and heavy-duty vehicles contribute 40% and 60% of the emissions of a given volume source, respectively, the initial vertical dimension would be (0.4 * 2.6) + (0.6 * 6.8) = 5.1 meters

EPA Guidance on Determining Initial Vertical Dispersion Coefficient (Szinit)

• Calculate Szinit
  – Divide the initial vertical dimension of the source by 2.15
  – For typical light-duty vehicles, this corresponds to an Szinit of 1.2 meters
  – For typical heavy-duty vehicles, the value of Szinit is 3.2 meters
Constructing an Input File – AERMOD

** STARTING
**
** Xcoord  Ycoord  (m)  (m)
**
** DISCCART  485.0  193.0
**
** FINISHED

Constructing an Input File – AERMOD

** STARTING
** SURFFILE  23155_2008-2012.sfc
** PROFFILE  23155_2008-2012.pfl
** SURFDATA  23155  2008
** UAIRDATA  23230  2008
** PROFBASE  0.0
**
** FINISHED
Constructing an Input File – AERMOD

```
OU STARTING
RECTABLE 24 1ST
MAXTABLE 24 50
POSTFILE 24 ALL PLOT 5yr Avg24h.plt
POSTFILE ANNUAL ALL PLOT 5yr AvgAnnual.plt
OU FINISHED
```

Output File Structure – AERMOD

- In-class Demonstration
CAL3QHCRi – Improvements to EPA’s CAL3QHCR Model

• Improvements were made to CAL3QHCR to enhance its use for highway air quality analyses as described in:
  – Guideline on Air Quality Models (Title 40 of the Code of Federal Regulations, Part 51, Appendix W)
    • Subsection 4.2.2c – Refined analytical techniques for other special modeling applications involving highways
    • Subsection 5.2.2.2b – Source-specific analysis of complicated sources for PM$_{10}$ as specified in Subsection 4.2.2
    • Subsection 5.2.3a – CO impacts at roadway intersections
    • Subsection 5.2.4f – Localized NO$_2$ concentrations due to mobile sources
    • Subsection 5.2.5b – Effects of roadways and highways on Pb air quality

CAL3QHCRi – Improvements to EPA’s CAL3QHCR Model

– Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM$_{2.5}$ and PM$_{10}$ Nonattainment and Maintenance Areas
  • Highways and intersections for PM$_{2.5}$ and PM$_{10}$
– Guidelines for Air Quality Maintenance Planning and Analysis, Volume 9 (Revised): Evaluating Indirect Sources
  • Parking areas and similar types of indirect sources
– Near-road NO$_2$ Monitoring Technical Assistance Document (Draft)
  • Deleted from the final document
Need for CAL3QHCR Improvements

- CAL3QHCR remains the model of choice by many State Departments of Transportation for several reasons
  - Familiarity with CALINE3 and CAL3QHC
  - Consistency with other dispersion modeling conducted in the highway air quality analysis
    - There is no AERMOD alternative to CALINE3 or CAL3QHC
  - Computational efficiency of CAL3QHCR over AERMOD
    - CAL3QHCR runs approximately 6 times faster
  - CAL3QHCR may provide lower results than AERMOD
    - A factor of 2 for some applications

Need for CAL3QHCR Improvements

- Continue technical support
  - EPA’s version of the CAL3QHCR model can be obtained through their SCRAM website
  - CAL3QHCR is not maintained by EPA and is no longer updated; therefore, technical support for the model code is not available through OAQPS
CAL3QHCRi Improvements

- Simplify and update the input file structure
- Computer processing enhancements
- Advanced function to account for the variability of emissions, traffic, and signalization (ETS) patterns
- Add the capability to process multiple years of meteorology in a single simulation
- Update the output file structure

CAL3QHCRi Improvements

- Improvements were made without affecting the concentration estimates produced
  - Consequently, the preferred status of the model is unchanged
    (40 CFR 51 Appendix W, Section 3.1.2b)
Concentration Estimates Produced by CAL3QHCRi Versus CAL3QHCR

<table>
<thead>
<tr>
<th>Year</th>
<th>CAL3QHCRi</th>
<th>U.S. EPA CAL3QHCR 13196</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2006</td>
<td>2007</td>
</tr>
<tr>
<td>Receptor</td>
<td>117</td>
<td>117</td>
</tr>
<tr>
<td>Wind Direction</td>
<td>300</td>
<td>314</td>
</tr>
<tr>
<td>Julian Day</td>
<td>65</td>
<td>14</td>
</tr>
<tr>
<td>Hour</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Max 24-hr Avg</td>
<td>3.04114</td>
<td>2.83805</td>
</tr>
<tr>
<td>Receptor</td>
<td>294</td>
<td>294</td>
</tr>
<tr>
<td>Julian Day</td>
<td>38</td>
<td>5</td>
</tr>
<tr>
<td>No. of Calms</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>2nd Max 24-hr Avg</td>
<td>2.93632</td>
<td>2.56604</td>
</tr>
<tr>
<td>Receptor</td>
<td>117</td>
<td>294</td>
</tr>
<tr>
<td>Julian Day</td>
<td>37</td>
<td>32</td>
</tr>
<tr>
<td>No. of Calms</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Max Annual Avg</td>
<td>0.97561</td>
<td>0.95755</td>
</tr>
<tr>
<td>Receptor</td>
<td>294</td>
<td>294</td>
</tr>
<tr>
<td>No. of Calms</td>
<td>658</td>
<td>966</td>
</tr>
<tr>
<td>Max 5-yr Qtr 24-hr</td>
<td>2.69811</td>
<td>Q1</td>
</tr>
<tr>
<td>Receptor</td>
<td>294</td>
<td>294</td>
</tr>
<tr>
<td>No. of Calms</td>
<td>4430</td>
<td>4430</td>
</tr>
</tbody>
</table>

Streamlined Management of Input Files

- A single input data file along with a single meteorological data file are required to complete a simulation with multiple (e.g., 5) years of meteorology.
- Contrast this to EPA’s version of CAL3QHCR for a PM\(_{2.5}\) simulation, which requires 60 files:
  - 20 input data files (4 quarterly files for each of 5 years);
  - 20 meteorological data files; and
  - 20 control files.
Streamlined Management of Output Files

- Output files produced
  - One descriptive output file
  - One Emissions, Traffic, Signalization (ETS) file
  - One message file
  - Two two post files
  - Two plot files
- The output files simplify the process of completing design value computations for highway air quality analyses

Streamlined Management of Output Files

- Contrast this to EPA’s version of CAL3QHCR for a PM$_{2.5}$ simulation, which produces 100 files
  - 20 descriptive output files
  - 20 et1 files – intermediate computation file for processing ETS data
  - 20 et2 files – intermediate computation file for processing ETS data
  - 20 message files
  - 20 plot files
A CAL3QHCRi input file is organized into six groupings:

1. File management
2. Program controls and site variables
3. Receptor locations
4. ETS patterns
5. Background concentrations
6. Link configurations

Each line of data in the input file has a specific structure, generally consisting of:

- A five character pathway label in columns 1 through 5
- A parameter list (data values) in columns 6 through 132, as necessary
  - Data values for a record cannot be continued on the next line
- Example
  - #1: 'CAL3QHCR Example Analysis - PM2.5',60,175,0,0,1,0.3048,1

Data values are entered in free format (i.e., at least one space or a single comma is required to delimit the fields)
Input File Structure – CAL3QHCRI

- No space is required between the pathway label and parameter list
- Any number of spaces can separate data values in the parameter list
- Only a single comma may be used as a delimiter
- Do not use the tab key
- End the line after the last data value using the enter key with no extra spaces
- The order of data values is important

Input File Structure – CAL3QHCRI

- A five character pathway label for data records is incorporated
  - Its function is to provide a means to distinguish each data record or record type in an input file
  - Any five character combination can be used as a descriptor
    - Avoid using two asterisks or two blanks as the first two characters of a pathway label or the data record provided will be ignored
  - All fields in a data record must contain a valid entry or the model will fail to complete its execution
Input File Structure – CAL3QHCRi

• Comment lines and blank lines can be effectively used to annotate an input file
  – If the first two characters on a line contain two asterisks or two spaces, then any subsequent information provided on the line is ignored by the program
  – Blank lines can be used to separate the groupings of data
  – Comment lines can be used to document information and as column headings to label input data values

Input File Structure – CAL3QHCRi

• Numerical format of data fields in a record

<table>
<thead>
<tr>
<th>Format Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Character</td>
<td>A string of alphanumeric characters that are bracketed by single quotes (e.g., ‘SR 1 – NB Lanes’)</td>
</tr>
<tr>
<td>Integer</td>
<td>A number with no decimal point (e.g., 12)</td>
</tr>
<tr>
<td>Real</td>
<td>A number with a decimal point separating the whole number portion from the fractional number portion (e.g., 234.16)</td>
</tr>
</tbody>
</table>
# Records for File Management

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>MET:</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>'*.met'</td>
<td>Character</td>
<td>Name of file containing preprocessed meteorology</td>
</tr>
<tr>
<td>OUT:</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>'*.out'</td>
<td>Character</td>
<td>Name of file containing model printout</td>
</tr>
<tr>
<td>ETS:</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>'*.ets'</td>
<td>Character</td>
<td>Name of file containing ETS data</td>
</tr>
<tr>
<td>MSG:</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>'*.msg'</td>
<td>Character</td>
<td>Name of file containing simulation errors and other messages</td>
</tr>
<tr>
<td>PST1</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>'*.pst'</td>
<td>Character</td>
<td>Name of file containing concurrent model results in post format of 24-hour averages for PM2.5, PM-10, and OTHER or 1-hour averages for CO and NO2</td>
</tr>
<tr>
<td>PST2</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>'*.pst'</td>
<td>Character</td>
<td>Name of file containing concurrent model results in post format of annual averages for PM2.5, PM-10, NO2, and OTHER or 8-hour averages for CO</td>
</tr>
<tr>
<td>PLT1</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>'*.plt'</td>
<td>Character</td>
<td>Name of file containing high value model results in plot format of average quarterly 24-hour for PM2.5; 6th highest 24-hour for PM-10; 24-hour for OTHER; 2nd highest 1-hour for CO; or average 8th highest 1-hour for NO2</td>
</tr>
<tr>
<td>PLT2</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>'*.plt'</td>
<td>Character</td>
<td>Name of file containing high value model results in plot format of average annual for PM2.5, PM-10, NO2, and OTHER or 2nd highest 8-hour for CO</td>
</tr>
</tbody>
</table>

*User-created file; ^CAL3QHCRi-generated file

# Records for Program Control & Site Variables

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1:</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>'JOB'</td>
<td>Character</td>
<td>Job title/description, up to 40 characters</td>
</tr>
<tr>
<td>ATIM</td>
<td>Real</td>
<td>Run averaging time (min)</td>
</tr>
<tr>
<td>Z0</td>
<td>Real</td>
<td>Surface roughness (or roughness length) (cm)</td>
</tr>
<tr>
<td>VS</td>
<td>Real</td>
<td>Settling velocity (cm/s)</td>
</tr>
<tr>
<td>VD</td>
<td>Real</td>
<td>Deposition velocity (cm/s)</td>
</tr>
<tr>
<td>NR</td>
<td>Integer</td>
<td>Number of receptors</td>
</tr>
<tr>
<td>SCAL</td>
<td>Real</td>
<td>Scale conversion factor, user units to meters</td>
</tr>
<tr>
<td>IOPT</td>
<td>Integer</td>
<td>Output units, 1 = feet; 0 = meters</td>
</tr>
<tr>
<td>#2:</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>'RUN'</td>
<td>Character</td>
<td>Run title/description, up to 40 characters</td>
</tr>
<tr>
<td>NL</td>
<td>Integer</td>
<td>Number of links</td>
</tr>
<tr>
<td>JTIER</td>
<td>Integer</td>
<td>Tier approach, 1 = Tier I; 2 = Tier II</td>
</tr>
<tr>
<td>'MODE'</td>
<td>Character</td>
<td>Pollutant (units), 'CO' = CO (ppm); 'PM2.5' = PM2.5 (μg/m³); 'PM-10' = PM-10 (μg/m³); 'NO2' = NO2 (ppb); 'OTHER' = OTHER (μg/m³)</td>
</tr>
<tr>
<td>FLINK</td>
<td>Integer</td>
<td>Print link contributions, 1 = YES; 0 = NO</td>
</tr>
<tr>
<td>FAMB</td>
<td>Integer</td>
<td>Include background concentrations in results, 1 = YES; 0 = NO</td>
</tr>
<tr>
<td>'RU'</td>
<td>Character</td>
<td>Land use selection, 'R' = Rural; 'U' = Urban</td>
</tr>
<tr>
<td>#3:</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>STRM0</td>
<td>Integer</td>
<td>Processing start month</td>
</tr>
<tr>
<td>STRDY</td>
<td>Integer</td>
<td>Processing start day</td>
</tr>
<tr>
<td>STRYR</td>
<td>Integer</td>
<td>Processing start year</td>
</tr>
<tr>
<td>ENDMO</td>
<td>Integer</td>
<td>Processing end month</td>
</tr>
<tr>
<td>ENDDY</td>
<td>Integer</td>
<td>Processing end day</td>
</tr>
<tr>
<td>ENDRY</td>
<td>Integer</td>
<td>Processing end year</td>
</tr>
</tbody>
</table>
Pathway #1
- Averaging time should be 60 min, since predictions are performed for a 1-hour period
- Surface roughness should be within the range of 3 cm to 400 cm
- If gravitational settling is negligible, the settling velocity should be 0 cm/s
- If deposition effects are negligible, the deposition velocity should be 0 cm/s

Pathway #2
- To account for hourly variations in emissions and meteorology, specify a Tier II approach (JTIER = 2)
- The MODE parameter may be a pollutant name of up to five characters. Designations that currently control the pollutant label, format, and averaging time of the results are 'CO', 'PM2.5', 'PM-10', 'NO2', and 'OTHER'. Additional designations are used as the pollutant label; the format and averaging time are as provided for MODE = 'OTHER'.
- Typically, do not include background concentrations in the model run by entering values of 0.0. Background concentrations are usually determined separately and added to model results to calculate design values.
- For determining whether land use is rural or urban, refer to EPA's Guideline on Air Quality Models, section 7.2.3

Pathway #3
- Processing start and end dates should match the start and end dates of the preprocessed meteorology
- Typically, the start month and day are January 1 (01,01) and the end month and day are December 31 (12,31)
- 5 years of off-site meteorology are generally required, which can be processed in a single simulation, e.g., 01,01,06,12,31,10
- If available, use met files prepared for regulatory applications by the governing air agency
- Wind speeds should be at least 1 m/s

Pathway #4
- User units are defined by the SCAL parameter entered on the Pathway #1 record
- Receptors should always be located outside of the mixing zone (link width)
- Receptor height should represent the typical ground-level breathing height of 1.8 m (5.9 ft) or less
# Records for Emissions, Traffic, & Signalization Patterns

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>#5:</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>PMOY1 to PMOY12</td>
<td>Integer</td>
<td>Month of year patterns for ETS values; assigned in the order: Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec. An example distinguishing four seasonal patterns by quarter: 1,1,2,2,3,3,3,4,4,4,4,4. Up to 12 monthly patterns may be assigned.</td>
</tr>
<tr>
<td>#6:</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>PHOD1 to PHOD24</td>
<td>Integer</td>
<td>Ending hour of day patterns for ETS values; assigned in the order: 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24. An example distinguishing four hourly patterns to represent the morning peak, midday, afternoon peak, and overnight: 1,1,1,1,1,1,2,2,2,3,3,3,3,3,3,3,4,4,4,1,1,1,1,1. Up to 24 hourly patterns may be assigned.</td>
</tr>
<tr>
<td>#7:</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>PDOW1 to PDOW7</td>
<td>Integer</td>
<td>Day of week patterns for ETS values; assigned in the order: Mon Tue Wed Thu Fri Sat Sun. An example distinguishing weekday and weekend travel: 1,1,1,1,1,2,2. Up to 7 daily patterns may be assigned.</td>
</tr>
</tbody>
</table>

**NOTES:**
- Pathways #5, 6, and 7
  - The emissions, traffic, and signalization data reflected in the MOVES modeling should be assigned to the relevant months, hours, and/or days using appropriate month of year, hour of day, and day of week ETS patterns.

# Records for Background Concentrations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>#8:</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>BKG</td>
<td>Real</td>
<td>Hourly ambient background concentrations (ppm for CO; ppb for NO₂; µg/m³ for PM2.5, PM-10, and OTHER) for each month of year ETS pattern. *** Repeat in succession for each of hour of day ETS pattern, then for each day of week ETS pattern. ***</td>
</tr>
</tbody>
</table>

**NOTES:**
- Pathway #8
  - Typically, hourly ambient background concentration will be set to zero. Background concentrations are usually determined separately and added to model results to calculate design values.
Pathway #9:

- A new link is required when there is a change in link width, link orientation, traffic volume, travel speed, or emission factor.
- For a succession of links, the start coordinates of the next link usually equals the end coordinates of the prior link, i.e., no gaps or overlaps.
- In most cases, a link type of at-grade (‘AG’) and a source height of 0 m should be used.
- Source height should be within ± 10 m (± 32 ft).
- Mixing zone width is defined as the width of the travelled roadway plus 3 m (10 ft) on either side.
- Link length must always be greater than the mixing zone width.

### Records for Link Configurations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>#9:</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>LNK</td>
<td>Character</td>
<td>Link name, up to 20 characters</td>
</tr>
<tr>
<td>IQ</td>
<td>Character</td>
<td>Traffic flow; ‘F’ = free-flow link; ‘Q’ = queue link</td>
</tr>
<tr>
<td>TYP</td>
<td>Character</td>
<td>Link type, ‘AG’ = at-grade; ‘FL’ = fill; ‘BR’ = bridge; and ‘DP’ = depressed</td>
</tr>
<tr>
<td>XL1</td>
<td>Real</td>
<td>Link X-coordinate start point (user units)</td>
</tr>
<tr>
<td>YL1</td>
<td>Real</td>
<td>Link Y-coordinate start point (user units)</td>
</tr>
<tr>
<td>XL2</td>
<td>Real</td>
<td>Link X-coordinate end point (user units)</td>
</tr>
<tr>
<td>YL2</td>
<td>Real</td>
<td>Link Y-coordinate end point (user units)</td>
</tr>
<tr>
<td>SH</td>
<td>Real</td>
<td>Source height (user units)</td>
</tr>
<tr>
<td>WL</td>
<td>Real</td>
<td>Mixing zone width (user units)</td>
</tr>
<tr>
<td>NLANES</td>
<td>Integer</td>
<td>Number of travel lanes for queue link (required only if IQ = ‘Q’)</td>
</tr>
<tr>
<td>NL</td>
<td>Integer</td>
<td>Number of links</td>
</tr>
</tbody>
</table>

### Records for Link Configurations

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Format</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>#10:</td>
<td>-</td>
<td>Pathway label</td>
</tr>
<tr>
<td>VPHL</td>
<td>Real</td>
<td>Hourly traffic volume (veh/hr) for each month of year ETS pattern</td>
</tr>
<tr>
<td>EFL</td>
<td>Real</td>
<td>Hourly emission factor (g/veh-mi) for each month of ETS pattern</td>
</tr>
</tbody>
</table>

*** Repeat in succession for each of hour of day ETS pattern, then for each day of week ETS pattern. ***

| #11:      | -      | Pathway label (required only if IQ = ‘Q’) |
| CAVG      | Real   | Average total signal cycle length (s) for each month of year ETS pattern |
| RAVG      | Real   | Average red signal cycle length (s) for each month of ETS pattern |
| YFAC      | Real   | Clearance lost time (s) for each month of ETS pattern |

*** Repeat in succession for each of hour of day ETS pattern, then for each day of week ETS pattern. ***

| #12:      | -      | Pathway label (required only if IQ = ‘Q’) |
| SFR       | Real   | Saturation flow rate (vphpl) for each month of year ETS pattern |
| ST        | Real   | Signal type for each month of ETS pattern, 1 = pre-timed; 2 = average; and 3 = semi-actuated |
| AT        | Real   | Arrival rate for each month of ETS pattern, 1 = worst; 2 = below average; 3 = average; 4 = above average; and 5 = best |

*** Repeat in succession for each of hour of day ETS pattern, then for each day of week ETS pattern. ***
Records for Link Configurations –
Notes

• Pathway #10:
  – Hourly traffic volume and emission factors are applied uniformly to the entire link length
  – Emission factors are defined as g/veh-mi
    • Use the latest version of MOVES; may chose the “Emission Rates” option
    • All relevant pollutants and processes should be summed for a single “rateperdistance” emission factor per link
      • MOVES post-processing scripts are available to complete this step
• Pathway #11:
  – For clearance lost time, a default value of 2 s may be used in the absence of locally derived values
• Pathway #12:
  – For saturation flow rate, a default value of ~1800 vehicles per hour, which is representative of an urban intersection, may be used in the absence of locally derived values
  – For signal type, a default value of 1 (pre-timed) may be used in the absence of locally derived values
  – For arrival rate, a default value of 3 (average progression) may be used in the absence of locally derived values

Constructing an Input File – CAL3QHCRi

FILE MANAGEMENT
**** Meteorology File
MET: 'CAL3QHCR5yr.met'
**** Output File
OUT: 'CAL3QHCR.out'
**** ETS File
ETS: 'CAL3QHCR.ets'
**** Message File
MSG: 'CAL3QHCR.msg'
**** Post File - Concurrent 24-hr averages
PST1 'CAL3QHCR24hr.pst'
**** Post File - Concurrent annual averages
PST2 'CAL3QHCRAnnual.pst'
**** Plot File - Highest 5-yr average 24-hr by quarter
PLT1 'CAL3QHCR5yr Avg24hr.plt'
**** Plot File - 5-yr average annual
PLT2 'CAL3QHCR5yr AvgAnnual.plt'
Constructing an Input File – CAL3QHCRi

PROGRAM CONTROL & SITE VARIABLES

**** 'JOB', ATIM, ZO, VS, VD, NR, SCAL, IOPT
#1: 'CAL3QHCR Example Analysis - PM2.5', 60, 175, 0, 0, 1, 0, 3048, 1

**** 'RUN', NL, JTIER, 'MODE', FLINK, FAMB, 'RU'
#2: '2006-2010 Annual Meteorology', 1, 2, 'PM2.5', 0, 0, 'U'

**** STARTMO, STARTDY, STARTYR, ENDMO, ENDDY, ENDYR
#3: 1, 1, 6, 12, 31, 10

RECEPTOR LOCATIONS

[Repeat in succession for each Receptor = 1 to NR]

**** 'RCP', XR, YR, ZR
#4: '1', 29.5, 698.2, 5.0

ETS PATTERNS

**** PMOY1, PMOY2, PMOY3, ..., PMOY11, PMOY12
#5: 1, 1, 1, 2, 2, 2, 3, 3, 3, 4, 4, 4

**** PHOD1, PHOD2, PHOD3, ..., PHOD23, PHOD24
#6: 1, 1, 1, 1, 1, 1, 2, 2, 3, 3, 3, 3, 3, 3, 3, 3, 3, 4, 4, 4, 1, 1, 1, 1, 1

**** PDOW1, PDOW2, PDOW3, PDOW4, PDOW5, PDOW6, PDOW7
#7: 1, 1, 1, 1, 1, 1, 1

BACKGROUND CONCENTRATIONS

[Repeat in succession for each hour of day ETS pattern, then for each day of week ETS pattern]

**** PMOY1, PMOY2, PMOY3, PMOY4
#8: 0, 0, 0, 0
#9: 0, 0, 0, 0
#10: 0, 0, 0, 0
#11: 0, 0, 0, 0
Constructing an Input File – CAL3QHCRi

LI NK CONFI GURAT IONS

** * [ Repeat #9 and #10 in succession for each Link = 1 to NL ]

** * [ Repeat #10 in succession for each hour of day ETS pattern, then for each day of week ETS pattern ]

** * 'LNK', 'I Q', 'TYP', X1, Y1, X2, Y2, SH, WL, (for, I Q= 'F')

#9: 'NW ramp', 'F', 'AG', 957.4, 2236.4, 1150.7, 1971.4, 0.0, 43.7

** PDOW1 for PHOD1 to PHOD4: VPHL - | EFL -

** PMOY1, PMOY2, PMOY3, PMOY4, PMOY1, PMOY2, PMOY3, PMOY4

#10: 186, 186, 186, 186, 0.057850, 0.040397, 0.031504, 0.038953

#10: 404, 404, 404, 404, 0.062932, 0.043161, 0.032228, 0.041529

#10: 186, 186, 186, 186, 0.054575, 0.036239, 0.030592, 0.035091

#10: 404, 404, 404, 404, 0.050415, 0.034508, 0.030593, 0.03955

Output File Structure – CAL3QHCRi

Example eAnalyzer ysisPACS.out

<table>
<thead>
<tr>
<th>Receptor Number</th>
<th>Quarter 1 Conc</th>
<th>Quarter 2 Conc</th>
<th>Quarter 3 Conc</th>
<th>Quarter 4 Conc</th>
</tr>
</thead>
<tbody>
<tr>
<td>7701</td>
<td>0.41650</td>
<td>0.27233</td>
<td>0.26424</td>
<td>0.31863</td>
</tr>
<tr>
<td>7702</td>
<td>0.45964</td>
<td>0.30880</td>
<td>0.29488</td>
<td>0.35012</td>
</tr>
<tr>
<td>7703</td>
<td>0.51440</td>
<td>0.35384</td>
<td>0.33481</td>
<td>0.38641</td>
</tr>
<tr>
<td>7704</td>
<td>0.51440</td>
<td>0.35384</td>
<td>0.33481</td>
<td>0.38641</td>
</tr>
<tr>
<td>294</td>
<td>2.69811*</td>
<td>1.95892*</td>
<td>1.84787*</td>
<td>2.01432*</td>
</tr>
<tr>
<td>319</td>
<td>1.55289</td>
<td>1.08285</td>
<td>1.02109</td>
<td>1.11396</td>
</tr>
<tr>
<td>320</td>
<td>1.11343</td>
<td>0.79660</td>
<td>0.73284</td>
<td>0.82467</td>
</tr>
<tr>
<td>321</td>
<td>0.78302</td>
<td>0.59265</td>
<td>0.53724</td>
<td>0.61956</td>
</tr>
</tbody>
</table>
Output File Structure – CAL3QHCRi

Example Analysis PM2.5.out

<table>
<thead>
<tr>
<th>Receptor Number</th>
<th>Average Conc of Days</th>
<th>Hours</th>
<th>Cal cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.07873</td>
<td>1826</td>
<td>C4430</td>
</tr>
<tr>
<td>2</td>
<td>0.09139</td>
<td>1826</td>
<td>C4430</td>
</tr>
<tr>
<td>3</td>
<td>0.10572</td>
<td>1826</td>
<td>C4430</td>
</tr>
</tbody>
</table>

Program terminated normally

Met Data Processing Steps

- Step 1 – Surface Meteorology can be obtained from a variety of sources
- Data should be selected based on its spatial and temporal representativeness with respect to the transport and dispersion conditions of the project area considering:
  - Proximity of the met monitoring site to the project area;
  - Complexity of the terrain;
  - Exposure of the met monitoring site; and
  - Period of time during which data are collected
**Met Data Processing Steps**

1. Obtain Surface Meteorology
2. Obtain Upper Air Meteorology
3. Quality Assurance / Quality Control
4. Convert Surface Data to Assessable Format, if needed
5. Process Surface and Upper Air Data to Obtain Met Files

**• The most predominant source of surface data is the National Weather Service (NWS) National Climatic Data Center (NCDC)**

- Recent data from the Automated Surface Observation System (ASOS) are collected in rolling averages stored every minute
  - AERMINUTE averages minute-by-minute wind measurements over an hour
- Conventional, human observations are based on a single 2-minute average taken during the hour to represent the hour

**• National Climatic Data Center**

- Free data access
  - http://www.ncdc.noaa.gov/data-access/quick-links#dsi-3505
- Integrated Surface Hourly Database (ISHD)
- ASOS1-minute data
Met Data Processing Steps

1. Obtain Surface Meteorology
2. Obtain Upper Air Meteorology
3. Quality Assurance / Quality Control
4. Convert Surface Data to Assessable Format, if needed
5. Process Surface and Upper Air Data to Obtain Met Files

- EPA Surface Databases
  - [http://www.epa.gov/ttn/scram/metobsdata_databases.htm](http://www.epa.gov/ttn/scram/metobsdata_databases.htm)

Step 2 – Upper Air Meteorology can also be obtained from a variety of sources

Chief among them is the NCDC, National Oceanic and Atmospheric Administration (NOAA)

- If radiosonde data require processing to obtain mixing heights, process the data using EPA’s Mixing Height Program
  - [http://www.epa.gov/ttn/scram/metobsdata_procaccprogs.htm](http://www.epa.gov/ttn/scram/metobsdata_procaccprogs.htm)
Met Data Processing Steps

1. Obtain Surface Meteorology
2. Obtain Upper Air Meteorology
3. Quality Assurance / Quality Control
4. Convert Surface Data to Assessable Format, if needed
5. Process Surface and Upper Air Data to Obtain Met Files

- **NOAA Earth Research Laboratory (ERSL)**
  - NOAA/ESRL radiosonde database
    - [http://www.esrl.noaa.gov/raobs/](http://www.esrl.noaa.gov/raobs/)

- **EPA Upper Air Databases**
  - [http://www.epa.gov/ttn/scram/metobsdata_databases.htm](http://www.epa.gov/ttn/scram/metobsdata_databases.htm)
Met Data Processing Steps

- **Step 3 – Refer to EPA’s Quality Assurance / Quality Control requirements**
  - “Procedures for Substituting Values for Missing NWS Meteorological Data for Use in Regulatory Air Quality Models”
    - [http://www.epa.gov/ttn/scram/surface/missdata.txt](http://www.epa.gov/ttn/scram/surface/missdata.txt)

- **Step 4 – Convert Surface Data to an accessible format, if needed**
  - Refer to Chapter 4 in “Analysis of the Affect of ASOS-Derived Meteorological Data on Refined Modeling”
Met Data Processing Steps

1. Obtain Surface Meteorology
2. Obtain Upper Air Meteorology
3. Quality Assurance / Quality Control
4. Convert Surface Data to Assessable Format, if Needed
5. Process Surface and Upper Air Data to Obtain Met Files

- Step 5 – Process Surface and Upper Air Data to obtain Meteorological Data Files
  - AERMET / MPRM
    - Stage 1: Extract and quality assurance
    - Stage 2: Merge
    - Stage 3: Process and create files for use in dispersion modeling

- Some state and local agencies may have 5 years of preprocessed met data available
  - These are typically processed for use with AERMOD
- If using preprocessed data, determine if the data is representative of the project area following EPA guidance
Met Data Processing Steps

1. Obtain Surface Meteorology
2. Obtain Upper Air Meteorology
3. Quality Assurance / Quality Control
4. Convert Surface Data to Assessable Format, if Needed
5. Process Surface and Upper Air Data to Obtain Met Files

- EPA Meteorological Processors
  - http://www.epa.gov/ttn/scram/metobsdata_proccprogs.htm
Phoenix, Arizona
February 17 - 20, 2015

EPA Meteorological Accessory Programs
– http://www.epa.gov/ttn/scram/metobsdata_procaccprogs.htm

Met Data Processing Steps

1. Obtain Surface Meteorology
2. Obtain Upper Air Meteorology
3. Quality Assurance / Quality Control
4. Convert Surface Data to Assessable Format, if Needed
5. Process Surface and Upper Air Data to Obtain Met Files

- Step 6 – Add a step in processing met data files for the EPA version of CAL3QHCR* to account for seasonal variations in emissions
  - Segregate files by quarter:
*Does not apply To CAL3QHCRi
Background Concentrations

Ambient Concentration = Background + Project (Local) Component + Other Nearby Sources not Reflected in Background

- Representative background concentrations are typically evaluated and chosen through the interagency consultation process
- Usually determined based on:
  - Current data from one or more ambient air quality monitors or
  - Future predictions from a chemical transport model
- The same background concentration is applied to modeling results for all receptors for all build and no-build scenarios
Design Values

- Ambient concentration statistic appropriate for comparison to a National Ambient Air Quality Standard (NAAQS)

- PM2.5
  - Annual – arithmetic mean, averaged over 3 years
    - 15.0 µg/m³ (1997)
    - 12.0 µg/m³ (2012)
  - 24-hour – 98th percentile, averaged over 3 years
    - 65 µg/m³ (1997)
    - 35 µg/m³ (2012)

- PM10
  - 24-hour – not to be exceeded more than once per year on average over 3 years
    - 150 µg/m³

- CO
  - 8-hour – not to be exceeded more than once per year
    - 9 ppm
  - 1-hour – not to be exceeded more than once per year
    - 35 ppm
Recommendations for Streamlining the Modeling Process

- Conduct processing steps in parallel rather than in series
  - Traffic analysis
  - Emission analysis
  - Dispersion analysis (link and receptor locations)
- Segregate Links – define highway segments with shared characteristics
- Adopt Link IDs common to each process
- Use Link IDs to merge data from each process to supply air dispersion model input templates

Defining Links

- Traffic Analysis
  - Volume
  - Vehicle speed
  - Truck percentage
- Issues (especially for congestion mitigation projects)
  - It may be important to segregate hourly vehicle activity during peak traffic periods instead of averaging over a 3-hour period – both options available per EPA guidance
  - In general, do not rely on regional travel demand models for project scale vehicle speeds, especially near signalized intersections and other traffic controls
Defining Links

• Emissions Analysis
  – Prepare speed look-up tables segregated by
    • Light-duty and heavy-duty vehicles (non-trucks & trucks)
    • Road type
    • Appropriate time periods (months and hours, as applicable)
    • Roadway grade
  – Project scale inputs that typically do not vary by link
    • Vehicle age distribution
    • Alternative vehicle fuels & technology
    • Fuel supply & formulation
    • Meteorology

Defining Links

• Dispersion Analysis
  – Highway width
  – Orientation or bearing
  – Traffic activity affecting emissions
    • Volume
    • Speed
    • Truck percentage
## Dispersion Model Input File Templates – Merging Traffic Data

<table>
<thead>
<tr>
<th>Dispersion Model Input File Templates</th>
<th>– Merging Traffic Data</th>
</tr>
</thead>
<tbody>
<tr>
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## Dispersion Model Input File Templates – Merging Emissions Data

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<tbody>
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**QL (months=1, month=1) PM2.5 MOVES2016b emission factor (g/MMT)**

<table>
<thead>
<tr>
<th>Calendar Year</th>
<th>Fuel Speed (Km/h)</th>
<th>Non-Trucks</th>
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<td>4, TDT</td>
<td>0.3797087</td>
<td>0.1708183</td>
<td>0.0797184</td>
<td>0.0897471</td>
</tr>
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Dispersion Model Input File Templates
– Merging Link Data

Dispersion Model Input File Templates
– Merging Receptor Data
Dispersion Model Input File Templates
– Merging Data into AERMOD

[Program controls]

[Highway config]

[Emissions]

[Receptor locations]

[Meteorology]

[Output options]
Dispersion Model Input File Templates
– Merging Data into CAL3QHCRi

### FILE MANAGEMENT
- **INPUT FILE**: `2015_0220_00_01.txt`
- **Output File**: `2015_0220_00_01.out`
- **ETS FILE**: `2015_0220_00_01.ets`
- **Message File**: `2015_0220_00_01.msg`
- **Post File 1**: Concurrent 24-hr averages
- **Post File 2**: Concurrent annual averages
- **Plot File 1**: Highest 1-hr average 24-hr by quarter
- **Plot File 2**: Summary of all CAL3QHCRi output

### PROGRAM CONTROL & SITE VARIABLES
- **100**
  - **AIR**: 20
  - **VS**: 100
  - **W**: 0
  - **NR**: 0
  - **SCAL**: 0.1000
  - **IDPT**: 1

- **200**: 2000-2012 Meteorology
  - **ATM**: 50
  - **FDR**: 2
  - **HR**: 2
  - **W**: 0
  - **U**: 0

### RECEPTOR LOCATIONS
- **Repeat in succession for each receptor > 1 or H**
  - **X**: 0
  - **Y**: 0
  - **Z**: 0

### ETS PATTERNS
- **PEN1**: 1
  - **PEN2**: 1
  - **PEN3**: 1
  - **PEN4**: 1
  - **PEN5**: 1

### BACKGROUND CONCENTRATIONS
- **Repeat in succession for each hour of day ETS pattern, then for each day of week ETS patterns**

### LNK CONFIGURATIONS
- **Repeat K0 in succession for each hour of day ETS pattern, then for each day of week ETS patterns**

### EMISSIONS
- **Repeat H00 in succession for each hour of day ETS pattern, then for each day of week ETS patterns**

---

**meteorology**

**output options**

**program control**

**receptor locations**

**highway config**

**emissions**
Receptor / Volume-source Spacing Utility Program

- Procedure based on highway right-of-way configuration
- Receptor spacing utility program application
- A similar utility program has been developed to establish volume source spacing based on highway centerline coordinates

Freeway Links and Right-of-Way
Freeway Links and Receptor Network

Arterial Links
Arterial Links and Receptor Network

Processing CAL3QHCR Met Data – CAL3Rmet

CAL3Rmet is a utility program for creating meteorological data sets for use in the U.S. Environmental Protection Agency’s (EPA) CAL3QHCR air dispersion model based on the U.S. EPA’s Meteorological Processor for Regulatory Models (MPRM) program. The process is completed in 6 steps:

1. **STEP 0** - Assemble Surface and Upper Air data from AERQMT processed files
2. **STEP 1** - Extract and QA data by completing MPRM Stage 1 processing
3. **STEP 2** - Merge data for completing MPRM Stage 2 processing
4. **STEP 3** - Create a file for use in the CAL3QHCR model by completing MPRM Stage 3 processing
5. **STEP 4** - Add surface mixing heights based on the U.S. EPA’s AEMUD formulation (optional)
6. **STEP 5** - Substitute values for missing meteorological data (optional)

CAL3Rmet helps ensure consistency among meteorological data sets developed using EPA’s AERQMT and AEMUD data processors.
Processing CAL3QHCR Met Data – CAL3Rmet

Processing CAL3QHCR Met Data – CAL3Rmet
Processing CAL3QHCR Met Data – CAL3Rmet

Create a Met Data File for CAL3QHCR (MPM Stage 2)
Processing CAL3QHCR Met Data – CAL3Rmet

Add Urban Mixing Heights

Filename of CAL3QHCR Met Data: TestStage1.MET
Filename of AERMOD Surface Met Data: 31912_28_MIC
Urban Population

Add Urban Mixing Heights

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<thead>
<tr>
<th>Year</th>
<th>Month</th>
<th>Day</th>
<th>Time</th>
<th>Vector</th>
<th>Speed</th>
<th>Temp</th>
<th>Class</th>
<th>Height</th>
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Substitute Values for Missing Met Data

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</table>

87
Agency Experiences in Conducting PM Dispersion Modeling

- **AERMOD area sources versus CAL3QHCR line sources**
  - Lin and Vallamsundar (IL DOT study) observed 2.1 times higher predictions of annual average concentrations of PM$_{2.5}$ for highways configured as AERMOD area sources versus CAL3QHCR line sources for a freeway interchange in Joliet, Illinois

- **AERMOD area sources versus AREMDO volume sources**
  - Schewe reported 1.8 to 3.8 times higher concentration predictions for highways configured as AERMOD volume sources versus AERMOD area sources

Agency Experiences in Conducting PM Dispersion Modeling

- **AERMOD area sources versus AERMOD volume sources**
  - Pasch, et al. (Caltrans study) found that the differences in peak concentrations predicted for highways configured as AERMOD area sources versus AERMOD volume sources narrowed by increasing the number of volume sources used in the simulation
  - Using modeling results for a hypothetical 1.1 mile freeway widening project, the study showed that
    - AERMOD produced 2.6 times higher concentrations for area sources versus a few (i.e., 22) large volume sources; whereas,
    - the concentration difference was only 10% higher for area sources versus many (i.e., 968) small volume sources
Phoenix, Arizona February 17 - 20, 2015

Agency Experiences in Conducting PM Dispersion Modeling – IL DOT Study

- IL DOT Study I-80 and I-55 Interchange near Joliet, Illinois
  - For an analysis year of 2015, the highest annual PM$_{2.5}$ concentration obtained from CAL3QHCR without the background was 2.7 µg/m$^3$ in the NE quadrant
  - This contrasts with the 5.8 µg/m$^3$ estimated with AERMOD

Agency Experiences in Conducting PM Dispersion Modeling – IL DOT Study

- IL DOT Study – Poplar Street Bridge, East St. Louis, Illinois
  - The highest annual PM$_{2.5}$ concentration obtained from CAL3QHCR without the background was 3.1 µg/m$^3$ for 2015
Agency Experiences in Conducting PM Dispersion Modeling – IL DOT Study

• IL DOT Study – Intersection of Algonquin and IL 53, Chicago
  – The highest annual PM$_{2.5}$ concentration obtained from CAL3QHCR without the background was 2.6 µg/m$^3$ for 2015

Agency Experiences in Conducting PM Dispersion Modeling – IL DOT Study

• IL DOT Study – Intersection of IL 3 and Piasa Lane, East St. Louis, Illinois
  – The highest annual PM$_{2.5}$ concentration obtained from CAL3QHCR without the background was 1.1 µg/m$^3$ for 2015
Agency Experiences in Conducting PM Dispersion Modeling – FHWA Study
Agency Experiences in Conducting PM Dispersion Modeling – FHWA Study

[Graphs showing different wind conditions and dispersion models]

Agency Experiences in Conducting PM Dispersion Modeling – FHWA Study

[Graphs showing different wind conditions and dispersion models]
Agency Experiences in Conducting PM Dispersion Modeling – FHWA Study

- Highway Configurations
  - Arterial intersection
  - Arterial midblock
  - Freeway interchange
  - Freeway mainline

- Emissions Models
  - MOVES2014
  - EMFAC2011

- Analysis Years
  - 2017 and 2037
## Generalized Case Studies of Project Scale PM Hot-spot Modeling

- **Emission Components**
  - Vehicle exhaust
    - Vehicle type (non-trucks and trucks)
  - Brake wear
  - Tire wear
  - Re-entrained road dust
  - Combined total

- **Air Dispersion Models**
  - AERMOD volume sources
  - AERMOD area sources
  - CAL3QHCR line sources

## Preliminary Results for Generalized Cases – CAL3QHCR

<table>
<thead>
<tr>
<th>Analysis Year</th>
<th>Generalized Case</th>
<th>Annual PM$_{2.5}$</th>
<th>24-hr PM$_{2.5}$</th>
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</thead>
<tbody>
<tr>
<td>2015</td>
<td>MOVES Arterial</td>
<td>2.5 µg/m$^3$</td>
<td>6 µg/m$^3$</td>
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<tr>
<td></td>
<td>MOVES Freeway</td>
<td>1.7 µg/m$^3$</td>
<td>3 µg/m$^3$</td>
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<tr>
<td></td>
<td>EMFAC Arterial</td>
<td>0.8 µg/m$^3$</td>
<td>2 µg/m$^3$</td>
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<tr>
<td></td>
<td>EMFAC Freeway</td>
<td>1.1 µg/m$^3$</td>
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<tr>
<td>2035</td>
<td>EMFAC Arterial</td>
<td>0.7 µg/m$^3$</td>
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<tr>
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</table>

Note: These results are subject to change
Graphical User Interfaces – FHWA’s CAL3i

- Integrates EPA’s CALINE3, CAL3QHC, and CAL3QHCR models into one computer program package
- Provides interactive graphical forms for entering data
- Extends the utility of the models
- Facilitates model operation in a Microsoft® Windows® environment

Regulatory Applicability

- CO Hotspot Analysis
  - CALINE3
    - Highways with freely flowing traffic
  - CAL3QHC
    - Highways with freely flowing traffic
    - Signalized intersections
  - CAL3QHCR
    - Tier I: account for hourly variations in transport meteorology over an annual data record
    - Tier II: account for hourly variations in emissions (traffic volumes and emission factors) and transport meteorology over a year
Regulatory Applicability

- PM Hotspot Analysis
  - CAL3QHCR
    - Tier II: account for hourly variations in emissions (traffic volumes and emission factors) and transport meteorology over a year

Data Forms

- Data entered via forms organized by:
  - Program control
  - Receptors
  - Links
  - Emissions
  - Meteorology
Extended Functionality

• Offers two screening options:
  – User enters all data required
  – Interface supplies EPA-recommended default data values

• Incorporates a utility for generating a simplified receptor / highway layout, allowing changes to:
  – Default configuration data
  – Default signal data

• Conducts data quality assurance/quality control checks
  – Missing data
  – Valid number verification
  – Out of range values

Extended Functionality

• Substantially increases the capacity for receptor and link analysis
  – No preset limits on the numbers of receptors and links – arrays allocated at runtime
    • Up from 20 receptors / 20 links for CALINE3
    • Up from 60 receptors / 120 links for CAL3QHC
    • Up from 60 receptors / 120 links for CAL3QHCR

• Provides screening results for multiple averaging times
  – 1-hour and 8-hour CO concentrations
Windows® Operation

- Constructing input files
- Program execution
- Displaying results
  - Summary table
  - Bar chart
  - Model printout

Windows® Operation

- Data file operations
  - Open and save data files
  - Import receptor, link, emissions, and/or meteorological data
  - Save results table and/or model output
  - Print data forms, data files, summary table, bar chart, and model output
  - Built-in tools for plotting wind roses, comparing build vs. no-build results, and summarizing emissions
### Enter / Edit Meteorology

![Image of Meteorology Entry/Editing interface]

### Model Results – Summary Table

![Image of Model Results Summary Table]

#### Model Results – Summary Table Details

<table>
<thead>
<tr>
<th>Date</th>
<th>Model</th>
<th>Yr (beg)</th>
<th>Yr (end)</th>
<th>T (deg)</th>
<th>CLA1</th>
<th>MRH (m)</th>
<th>R (deg)</th>
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<td>2015</td>
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Phoenix, Arizona
February 17 - 20, 2015

Model Results - Chart

Model Results - Printout
Additional Tools Planned

• Construct Wind Roses
  – Tables
  – Graphs

• Compute Design Values
  – Local component plus background

• Import MOVES Link Tables

Class Exercises –
AERMOD and CAL3QHCRi

• Refer to the Class Exercise Instructions