General Characteristics		
1	**Abstract of Model Capabilities**	CALPUFF is a multi-layer, multi-species, non-steady state puff dispersion model which can simulate the effects of time- and space-varying meteorological conditions on pollutant transport, transformation, and removal. CALPUFF can use the three-dimensional meteorological fields computed by the CALMET model, or simple, single station winds in a format consistent with the meteorological files used to drive the ISC3 or the CTDM steady-state Gaussian models. CALPUFF contains algorithms for near-source effects such as building downwash, transitional plume rise, partial plume penetration, and subgrid scale terrain interactions as well as longer range effects such as pollutant removal (wet scavenging or dry deposition), chemical transformation, vertical wind shear, and overwater transport. Most of the algorithms contain options to treat the physical processes at different levels of detail, depending on the model application. Dispersion of heavier-than-air gases is not considered.
2	**Sponsor and/or Developing Organization**	Sponsor: California Air Resources Board (CARB) U.S. Environmental Protection Agency (U.S. EPA), U.S.D.A. Forest Service, Several industry and government agencies in Australia. Developer: Earth Tech (formerly Sigma Research)
3	**Last Custodian/ Point of Contact**	Joseph Scire Earth Tech Inc. (508) 371-4270 (508) 371-2468 **Fax** HYPERLINK mailto:jss@src.com **primary individual**
4	**Life-Cycle**	CALPUFF was originally developed for California Air Resources Board by Sigma Research. The Interagency Workgroup on Air Quality Modeling (IWAQM) has evaluated CALPUFF including comparisons with field tests. As a result the model has been enhanced to make it more suitable for meso-scale applications. The model is part of a modeling system that includes both pre- and post-processors including a 3-D meteorological model. The model is being disseminated by the U.S. EPA for general testing and review and should still be approved on a case-by-case basis for regulatory assessments.
5	**Model Description Summary**	Source types Point sources (constant or variable emissions) Line sources (constant emissions) Volume sources (constant or variable emissions with 1-hour time constant) Area sources Non-steady-state emissions and meteorological conditions Gridded 3-D fields of meteorological variables (winds, temperature) Spatially variable fields of mixing height, friction velocity, convective velocity scale, Monin-Obukhov length, precipitation rate Vertically and horizontally varying turbulence and dispersion rates Time-dependent source and emissions data Efficient sampling functions Integrated puff formulation Elongated puff (slug) formulation Dispersion coefficient ((y, (z) options Direct measurements of ((and ((Estimated values of (y and (z based on similarity theory Pasquill-Gifford (PG) dispersion coefficients (rural areas) McElroy-Pooler (MP) dispersion coefficients (urban areas) Vertical wind shear Puff splitting Differential advection and dispersion Plume rise Partial penetration Buoyant and momentum rise Stack tip effects Vertical wind shear Building downwash effects

5	**Model Description Summary** (Cont.)	Building downwash Huber-Snyder method Schulman-Scire method Subgrid scale complex terrain Dividing streamline, Hd: ! Above Hd, puff flows over the hill and experiences altered diffusion rates ! Below Hd, puff deflects around the hill, splits, and wraps around the hill Interface to the Emissions Production Model (EPM) Time-varying heat flux and emissions from controlled burns and wildfires Dry deposition Gases and particulate matter Three options: ! Full treatment of space and time variations of deposition with a resistance model ! User-specified diurnal cycles for each pollutant ! No dry deposition Overwater and coastal interaction effects Overwater boundary layer parameters Abrupt change in meteorological conditions, plume dispersion at coastal boundary Plume fumigation Chemical transformation options Pseudo-first-order chemical mechanism for SO2, (MESOPUFF II method) User-specified diurnal cycles of transformation rates No chemical conversion Wet Removal ! Scavenging coefficient approach ! Removal rate a function of precipitation intensity and precipitation type Graphical User Interface ! Point-and-click model setup and data input ! Enhanced error checking of model inputs ! On-line Help files
6	**Application Limitation**	Model is best applied to longer term industrial combustion sources and not short term chemical spills. Averaging times are long (minimum 1 hour) for input data (release rate and meteorology) and output. Heavier-than-air releases are not considered and chemical transformations are available for five chemicals. The model apparently has excellent longer range meso-scale capabilities that are normally not required for chemical spills analyses.
7	**Strengths/ Limitations**	User interface and documentation are easy to use. Output is detailed but cumbersome in that it provides much more information than necessary for most applications. Time scales are a minimum of 1 hour and, thus, are longer than needed for most chemical accident analyses. Probably, the most significant limitation, from the DOE perspective, is the lack of a front end spills model that computes evaporation, jet effects, etc. The model does not compute the area of impact above ERPG level. Also, it does not have a dense gas model.
8	**Model References**	! EPA, 1993: Interagency Workgroup on Air Quality Modeling (IWAQM) Phase I report: Interim Recommendations for Modeling Long Range Transport and Impacts on Regional Visibility. U.S. EPA, Research Triangle Park, NC ! EPA, 1995: A User's Guide for the CALPUFF Dispersion Model. EPA-454/B-95-006. U.S EPA, Research Triangle Park, N.C. ! EPA, 1995: User's Guide for the Industrial Source Complex (ISC3) Dispersion Models. United States Environmental Protection Agency, Office of Air Quality Planning and Standards. EPA 454/B-95-0036, U.S. EPA, Research Triangle Park, N.C., 27711. ! Perry, S.G., D.J. Burns, L.H. Adams, R.J. Paine, M.G. Dennis, M.T. Mills, D.G. Strimaitis, R.J. Yamartino, E.M. Insley, 1989: User's Guide to the Complex Terrain Dispersion Model Plus Algorithms for Unstable Situations (CTDMPLUS) Volume I: Model Description and User Instructions. EPA/600/8-89/041, U.S. Environmental Protection Agency, Research Triangle Park, N.C.

8	**Model References (Cont.)**	! Scire J.S., E.M. Insley, R.J. Yamartino, and M.E. Fernau, 1995: A User's Guide for the CALMET Meteorological Model. Prepared for the USDA Forest Service by Sigma Research/EARTH TECH, Concord, MA. ! Scire, J.S., E.M. Insley and R.J. Yamartino, 1990a: Model Formulation and User's Guide for the CALMET Meteorological Model. Prepared for the California Air Resources Board by Sigma Research Corporation, Concord, MA. ! Scire, J.S., D.G. Strimaitis and R.J. Yamartino, 1990b: Model Formulation and User's Guide for the CALPUFF Dispersion Model. Prepared for the California Air Resources Board by Sigma Research Corporation, Concord, MA. ! Scire, J.S., F.W. Lurmann, A. Bass and S.R. Hanna, 1984a: Development of the MESOPUFF II Dispersion Model. EPA-600/3-84-057, U.S. Environmental Protection Agency, Research Triangle Park, NC.
9	**Input Data/Parameter Requirements**	**The following input is required:** File containing the filename and path for each of the input and output (I/O) files used in the current run. If an I/O filename is not specified in the PUFFILES.DAT file, the model uses the default filenames shown in this table. Control file inputs Geophysical and hourly meteorological data, created by the CALMET meteorological model Single-station ASCII meteorological data in slightly modified ISC2-format Single-station ASCII meteorological data in slightly modified AUSPLUME format Source and emissions data for point sources with arbitrarily varying emission parameters (optional) Emissions data for area sources with time-varying emission parameters. Can be derived from EPM model files (optional). Emissions data for volume sources with time-varying emission parameters (optional) Emissions data for line sources with time-varying emissions parameters (optional) User-specified deposition velocities (optional) Hourly ozone measurements at one or more ozone stations (optional) User-specified chemical transformation rates (optional) Hourly turbulence measurements ((v, (w) (optional) Hill specifications from CTDM terrain processor (optional)
10	**Output Summary**	Unformatted data files containing gridded fields of time-averaged concentrations, time-averaged dry deposition fluxes, and time-averaged wet deposition fluxes are created with each run. The post-processing program CALPOST is designed to produce ranked tabulations of averages of selected concentration data from these data files. CALPOST writes a text file containing the input data summary and output tables.
11	**Applications**	Primarily applicable to longer term industrial sources, including multiple emissions from several source locations. Also, can be used to model effects of fires. See section 8 References above.
12	**User-Friendliness**	WINDOWS interface for CALPUFF, CALMET preprocessor, and CALPOST postprocessor. On-line help. There is an input parameter error checking screen that lists all the errors detected by the CALPUFF GUI (graphic user interface).
13	**Hardware-Software Interface Constraints/ Requirements**	**Computer operating system:** PC with WINDOWS (if GUI is used) or DOS **Computer platform:** **Disk space requirements:** 3 MB for unzipped files, 18 MB for installed system **Run execution time** (for a typical problem)**:** Run execution time for typical problem (CPU or Real Time): The memory required by CALPUFF is a strong function of the specified maximum array dimensions in the parameter file. However, as an example, CALPUFF required approximately 300 KB of memory for a test run with a 10 x 10 horizontal grid, with 5 vertical layers, and a maximum number of puffs of 100. This type of configuration may be suitable for evaluating the near-field impact of a small number of point sources. For studies involving long-range transport, memory requirements will typically be at least 8 MB, with more required for simulations involving large numbers of sources. The run time of CALPUFF will vary considerably depending on the model application. Variations of factors of 10–20 are likely, depending on the size of the domain, the number of sources, selection of technical options, and meteorological variables such as the mean wind speed. Because each puff is treated independently, any factor which influences the number and residence time of puffs on the computational grid will affect the run time of the model. **Programming language:** FORTRAN

13	**Hardware-Software Interface Constraints/ Requirements (Cont.)**	**Other computer peripheral information:** METSCAN is a meteorological preprocessor which performs quality assurance checks on the hourly surface meteorological data in the NCDC CD-144 format which is used as input to the SMERGE program. READ56 and READ62 are meteorological preprocessors which extract and process upper air wind and temperature data from standard data formats used by NCDC. READ56 and READ62 process TD-5600 and TD-6201 formatted data, respectively. SMERGE is a meteorological preprocessor which processes hourly surface observations from a number of stations in NCDC CD-144 format and reformats the data into a single file with the data sorted by time rather than station. PXTRACT is a meteorological preprocessor which extracts precipitation data for stations and a time period of interest from a fixed-length, formatted precipitation data file in NCDC TD-3240 format. PMERGE is a meteorological preprocessor responsible for reformatting the precipitation data files created by the PXTRACT program. PMERGE resolves "accumulation periods" into hourly values and flags suspicious or missing data. The output file can be formatted or binary, which can be directly input into the CALMET model, containing the precipitation data sorted by hour rather than station. CSUMM (a version of the Colorado State University Mesoscale Model) is a primitive equation wind field model which simulates mesoscale airflow resulting from differential surface heating and terrain effects. The diagnostic wind field model within CALMET contains options that allow wind fields produced by CSUMM to be combined with observational data as part of the CALMET objective analysis procedure. MM4-FDDA (Penn State/NCAR Mesoscale Model) is a prognostic wind field model with four-dimensional data assimilation. CALMET has been modified to incorporate MM4-FDDA winds into its Diagnostic Wind Model (DWM). **Portability**: Can be easily installed on IBM-compatible PC computers.
14	**Operational Parameters**	**Identify whether the code has any error diagnostic messages to assist the user in troubleshooting operational problems:** Approximately a third of the RSAC-5 program is devoted to error diagnostics. RSAC+ checks all fields to assure that data is in range for the given variable and that consistency in an input series is maintained. **Set up time for:** Setup up times are dependent on the complexity of the run being made. **Typical times are:** ***first-time user:*** .5-1 h ***experienced user:*** 5-10 min
15	**Surety Considerations**	**All quality assurance documentation:** The code has been used and reviewed by several different organizations, but no formal QA is mentioned in the documentation. **Benchmark runs:** None indicated. **Validation calculations:** **Verification with field experiments that has been performed with respect to this code:** Evaluated by IWAQM using tracer data collected during Cross-Appalachian Tracer
16	**Runtime Characteristics**	Setup Time (first run, subsequent run) There are so many input variables and model control switches that an initial run can take a long time to set up (i.e., minimum of several hours to days, depending on complexity of application). Subsequent runs with small changes in the data set can be set up much faster.

Specific Characteristics

Part A: Source Term Submodel Type

A1	**Source Term Algorithm?**	___YES ✔ NO

Part B: Dispersion Submodel Type (Not Applicable)

Part C: Transport Submodel Type

C1	**Prognostic**	Yes. Some applications use model for forecast processing.
C2	**Deterministic**	Yes
C4	**Frame of Reference**	✔ **Eulerian** __ **Lagrangian** __ **Hybrid** __ **Eulerian-Lagrangian**

Part D: Fire Submodel Type (Not Applicable)

Part E: Energetic Events Submodel Type (Not Applicable)

Part F: Health Consequence Submodel Type

F1	**For Chemical Consequence Assessment Models**	**Health effects:** __ **fatalities** __ **cancers** __ **latent cancers** __ **symptom onset** **Health criteria** __ **IDLH** __ **STEL** __ **TLV** __ **TWA** __ **ERPG** __ **TEEL** __ **AEGL** __ **WHO**

F1	**For Chemical Consequence Assessment Models**	**Health effects: __ fatalities __ cancers __ latent cancers __ symptom onset** **Health criteria** **__ IDLH __ STEL __ TLV __ TWA** **__ ERPG __ TEEL __ AEGL __ WHO** **Zones with flammable limits: __ UFL __ LFL** **Blast overpressure regions:** **Fire radiant energy zones:** **Risk qualification:** **Concentration: _✔_ single value _✔_ time-history __ integrated dose** **Probits:**
Part G: Effects and Countermeasures Submodel Type (Not Applicable)		
Part H: Physical Features of Model		
H2	**Release Elevation**	**_✔_ ground _✔_ roof**
H3	**Aerodynamic Effects from Buildings and Obstacles**	**_✔_ building wake _✔_ cavity _✔_ K-factors _✔_ flow separation** Huber-Snyder Schulman-Scire
H4	**Horizontal Plume Meander**	Can be adjusted for measurement times less than an hour.
H5	**Horizontal/Vertical Wind Shear:**	Yes
H6	**Mixing Layer**	**_✔_ trapping _✔_ lofting _✔_ reflection _✔_ penetration** **_✔_ inversion breakup fumigation __ temporal variability**
H7	**Cloud Buoyancy**	**_✔_ neutral [passive] __ dense [negative] _✔_ plume rise [positive]**
H9	**(Radio)chemical Transformation and In-Cloud Conversion Processes**	In-cloud transformation
H10	**Deposition**	**_✔_ gravitational setting _✔_ dry deposition _✔_ precipitation scavenging** **_✔_ resistance theory deposition __ simple deposition velocity _✔_ liquid deposition** **__ plateout and re-evaporation**
H13	**Temporally and Spatially Variant Mesoscale Processes**	**Urban heat island:** **Canopies:** **Complex terrain (land) effects: _✔_ mountain-valley wind reversals** **_✔_ anabatic winds _✔_ katabaic winds** **Complex terrain (land-water) effects: _✔_ seabreeze airflow trajectory reversals** **_✔_ Thermally Induced Boundary Layer definition _✔_ seabreeze fumigation** **_✔_ landbreeze fumigation** **Thunderstorm outflow:** **Temporally variant winds:** **High velocity wind phenomena: __ tornado __ hurricane __ supercane __ microburst**
Part I: Model Input Requirements		
I1	**Radio(chemical) and Weapon Release Parameters**	**Release rate: _✔_ Continuous __ Time dependent __ Instantaneous** **Release container characteristics: __ vapor temperature __ tank diameter** **__ tank height __ tank temperature __ tank pressure __ nozzle diameter** **__ pipe length** **Jet release: _ initial size __ shape** **__ concentration profile at end of jet affected zone** **Release dimensions: _ point __ line _ area** **Release elevation: _ ground __ roof __ stack**

I2	**Meteorological Parameters**	**Wind speed and wind direction: _single point ✔ single tower/multiple point ✔ multiple towers** **Temperature: _ single point ✔ single tower/multiple point _ multiple towers** **Dew point temperature: ✔ single point __ single tower/multiple point __ multiple towers** **Precipitation: __ single point __ single tower/multiple point ✔ multiple towers** **Turbulence typing parameters: __ temperature difference __ sigma theta __ sigma phi ✔ Monin-Obukhov length ✔ roughness length _ cloud cover __ incoming solar radiation ✔ user-specified** **Four dimensional meteorological fields from prognostic model:**
Part J: Model Output Capabilities (See Item 10)		
Part K: Model Usage Considerations (No Information Provided.)		